MATHEMATICAL MODELING OF SURFACE ROUGHNESS AND FORCES FOR TURNING OF EN-353

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I, VINAY KUMAR, Roll No. 2K16/PIE/19 student of M. Tech. (Production & Industrial Engineering), hereby declare that the project Dissertation titled "**MATHEMATICAL MODELLING OF SURFACE ROUGHNESS AND FORCES FOR TURNING OF EN-353**" which is submitted by me to the Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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I hereby certify that the project Dissertation titled **MATHEMATICAL MODELLING OF SURFACE ROUGHNESS AND FORCES FOR TURNING OF EN-353** which is submitted by VINAY KUMAR, Roll No. 2K16/PIE/19 Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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ABSTRACT

In manufacturing industries metal cutting, surface finish and material removal rate of a product is very crucial in determining the quality. Good surface finish not only assures quality, but also reduces manufacturing cost. Surface finish is important in terms of tolerances, it reduces assembly time and avoids the need for secondary operation, thus reduces operation time and leads to overall cost reduction. Besides, good-quality turned surface is significant in improving fatigue strength, corrosion resistance, and creep life.

This study focuses on analysing cutting parameters based on the Taguchi method, a powerful tool to design optimization for quality, is used to minimize surface roughness. A full factorial 27 experiments, the signal-to-noise (S:N) ratio, analysis of variance (ANOVA) and regression analysis are employed to investigate the cutting characteristics of mild steel bars(EN-353) using carbide cutting tools. The main objective is to study the effect of cutting speed, feed and depth of cut on surface roughness of mild steel in turning operation using carbide tool. Different cutting parameters have different influential on the surface finish. The cutting speed, feed and depth of cut were decide using the suitable range recommended; which were 36.313m/min, 80.29m/min and 125.66m/min are cutting speed, 0.05mm/rev, 0.10mm/rev and 0.15mm/rev for feed and lastly 0.6mm, 0.9mm and 1.2mm for depth of cut. The specimen was turned under different level of parameters and was measured the surface roughness using a Taylor Hobson’s Surtronic 3+. From the result, it is concluded that higher cutting speed and lower feed produce better surface finish. The optimum cutting parameters were 125.66m/min, 0.05mm/rev and 0.6mm, which produced minimum surface roughness of 1.33µm. According to the ANOVA analysis, feed is the dominant factor by 85.82%.

Keywords: Surface roughness, cutting forces, feed forces, thrust forces, Taguchi, ANOVA, Regression analysis and Taylor Hobson’s Surtronic 3+.

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NOMENCLATURE

Parameter	Description
Ra	Parameter of roughness
SR	Surface Roughness
ANOVA	Analysis of Variance
DOE	Design of Experiment
DOC	depth of cut

The motif (R) parameters

R	Mean depth of roughness motifs
Rx	Maximum depth of roughness motifs
Ar	Mean spacing of roughness motifs
Rsm	Mean width of profile
Pt	Maximum peak to valley height

CHAPTER 1

INTRODUCTION

1.1 Introduction

Lathe machine is the oldest machine tool that is still the most familiar used machine in the manufacturing industry to produce cylindrical parts. Lathes are machines that cut work pieces while they are rotated. Lathes are capable to produce fast, precision cuts, usually by index able tools and drills. They are predominantly effective for complex programs intended to make parts that would be infeasible to make on normal lathes.

Mechanical properties like fatigue behaviour, corrosion resistance, creep life, etc. depends on surface roughness. It also affects other functional attributes of products like contact resistance, wear, light reflection, lubrication, thermal or electrical conduction, noise and vibration, tolerance etc. Thus surface roughness generally plays important role and cannot be neglected. Better surface finish in turning operation can achieved by proper selection of machining parameters during turning, such as feed rate, cutting speed, depth of cut, tool angel, nose radius, etc.

In the past, numerous researchers extensively used statistical design of experiments for the investigation of optimum machining parameters for minimum surface roughness, minimum tool wear, maximum metal removal rate etc. in turning. Statistical design of experiments refers to the process of planning the experiment so that the appropriate data can be analysed by statistical methods, resulting in valid and objective conclusions. Response surface methodology (RSM), factorial design, and Taguchi methods are now widely used to obtain minimum surface roughness, minimum tool wear etc. in turning [1]

Taguchi technique was employed for the optimization of cutting parameters in turning hardened AISI 4140 steel [6] and same method was used to find the optimal cutting parameters for surface roughness in turning of AISI 1030 carbon steel using TiN coated tools [7]. The optimization of machining parameters was studied in turning AISI 1045 steel with coated carbide tool by using Taguchi design and ANOVA [8]. The influence of the machining parameters on the surface finish was investigated in turning D2 steel with TiN coated carbide insert by using Taguchi parameter design and response surface methodology [9].

Surface roughness prediction model has been developed in turning of mild steel workpiece, using response surface methodology [10]. The performance of a multilayer tungsten carbide tool by using response surface methodology was studied [11] in turning of AISI 1045 steel. Surface roughness prediction model [12] was developed by using RSM for hard turning of the bearing steel (AISI 52100) with mixed ceramic inserts, having different nose radius and different effective rake angles. The optimization of machining parameters in turning of E0300 alloy steel with respect to surface finish and minimum cost was studied [13]. Surface roughness model was developed for turning of femoral heads from AISI 316L stainless steel using Response surface methodology [14] and found depth of cut was a main influencing factor on the surface roughness. It increased with increasing the depth of cut. D-optimal design based on the response surface methodology was used for modelling and analysing the vibration and surface roughness in the precision turning of A6061-T6 with a diamond cutting tool [15].

The effects of cutting edge geometry, workpiece hardness, feed rate and cutting speed was investigated experimentally on surface roughness and forces in finish turning of hardened AISI H13 steel by using cubic boron nitrite inserts with two distinct edge preparations [16].

The effects of conventional and wiper inserts was studied [17] in turning of AISI 1045 steel. In this study, regression models and neural network models have been developed for the prediction of surface roughness, mean force and cutting power. Results indicated that lower surface roughness values are attainable with wiper tools.

The EN-353 is widely used in various industries such as automotive industries, aerospace and aircraft industries. The literature reveals that there is a lot of scope to optimize the machining parameters to obtain minimum surface roughness in turning of EN-353.

In the present work, response surface methodology is applied to determine the optimal turning parameters to achieve minimum surface roughness value for EN-353 steel under varying machining conditions. Present work includes the following:

- To find the relationship between the turning parameters (in the study: cutting speed, feed rate, nose radius and depth of cut) and the response factor (surface roughness).
- To find the optimal machining condition for achieving minimum surface roughness.

A widely known model to establish the SR is $R_a = f^2/32r$, where f is the feed rate and r is the nose radius. Undoubtedly, feed rate and nose radius affect SR the most [2]. The product value depends extremely on surface roughness. Decrease of SR quality also leads to decrease of product value. In field of production, particularly in engineering, the surface finish quality can be a significant importance that can affects the working of a component, and possibly its cost. SR has been obtaining responsiveness for numerous years in the machining industries. It is a vital design characteristic in many situations, such as parts subject to fatigue loads, precision fits, and fastener holes and so on.

In terms of tolerances, SR executes one of the greatest vital constraints for the machines and cutting parameters selection in process planning. Manufacturing industries are very much anxious about the quality of their products. They are concentrated on producing high quality products in time at minimum cost. Surface finish is one of the vital performance parameters that have to be constrained within appropriate limits for a specific process. Therefore, forecast or observing of the SR of machined components has been a significant area of research. SR is harder to accomplish and track than physical dimensions are, because comparatively many factors affect SR. Some of these aspects can be regulated and some cannot. Manageable process parameters include feed, cutting speed, tool geometry, and tool setup. Other factors, such as tool, work piece and machine vibration, tool wear and degradation, and work piece and tool material inconsistency cannot be controlled as easily. SR also affects numerous functional characteristics of parts, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of dispensing and holding a lubricant, coating or opposing fatigue. Therefore the preferred finish surface is usually specified and the appropriate are selected to reach the requisite quality. Several works have been reported in the broad field of tool condition monitoring. Researchers are trying to acquire a robust and exact model that can find a relationship between the cutting parameters and the SR of the machined products.

1.2 Types of Roughness

The subsequent roughness produced by a machining method can be thought of as the combination of two autonomous effects: Ideal roughness and Natural roughness.

1.2.1 Ideal Roughness

Ideal SR is a function of only feed and geometry. It signifies the finest possible finish which can be acquired for a given tool shape and feed. It can be attained only if the built-up-edge, chatter and inaccuracies in the machine tool movements are eliminated completely. For a sharp tool without nose radius, the maximum height of unevenness is given by:

$$R_{max} = f / (\cot \varphi + \cot \beta)$$

The SR value is given by:

$$R_a = R_{max} / 4$$

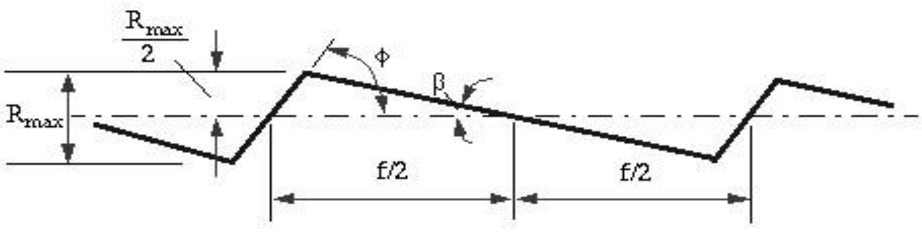

Fig. 1.1 Surface profile

f = Feed

Φ = Major cutting edge angle

B = working minor cutting edge angle

1.2.2 Natural Roughness

One of the key aspects contributing to natural SR is the existence of a built-up edge. Thus, greater the built up edge, the rougher would be the surface produced, and aspects tending to reduce chip-tool friction and to eradicate the built-up edge would give enhanced surface finish.

1.3 Cutting Parameters

It is significant task to select cutting parameters for achieving high cutting performance. However, this does not confirm that the selected cutting parameters have best or near best cutting performance for a specific machine and environment [3]. The important cutting parameters discussed here are cutting speed, feed and depth of cut.

1.3.1 Cutting Speed

All materials have an optimal cutting speed and it is expressed as the speed at which a point on the surface of the work passes the cutting edge or point of the tool and is normally given in meters/min. To calculate the cutting speed required,

$$\mathbf{V_c = \pi DN/1000}$$

Where: V_C = Cutting Speed of Metal (m/min), D = Diameter of Work piece, N = Spindle Speed (RPM)

1.3.2 Feed

The term ‘feed’ is used to define the distance the tool moves per revolution of the work piece and varies largely on the surface finish needed. For rough turning of soft material a feed of up to 0.25 mm/rev may be used and for tougher materials this should be decreased to a maximum of 0.10 mm/rev. For good finishing finer feed is recommended.

1.3.3 Depth of cut

It is the advancement of tool in the job in a direction perpendicular to the surface being machined. Depends upon Depth of cut cutting speed, rigidity of machine tool and tool material etc. Depth of cut normally varies between 1 to 5 mm for roughing operation and 0.05 to 1.2 mm for finishing operation.

1.3.4 Force analysis

1.3.4.1 Cutting force(F_C

This force is in the direction of primary motion. The cutting force constitutes about 70~80 % of the total force F and is used to calculate the power P required to perform the machining operation,

$$P = VF_c$$

Where v=velocity of tool

F_c=cutting force

1.3.4.2 Thrust force (Ft)

This force is in direction of feed motion in orthogonal cutting. The thrust force is used to calculate the power of feed motion

1.3.4.3 Feed force (F_f

The axial or feed force acts in the longitudinal direction. It is also called the feed force because it is in the feed direction of the tool. The radial or thrust force acts in the radial direction and tends to push the tool away from the workpiece.

1.3.5 Effect of cutting parameters

It is found in most of the cases SR decreases with increase in cutting speed and decrease in feed and depth of cut and cutting forces.

Since these cutting parameters will choose about the type of chips which we assume at the time of machining of a single constant material thus we have to examine them for no such built-up edge chips formation. At the optimal cutting speed at which the consequence of built up edge is insignificant, (high speed, ductile material) the profile of the cutting edge of the tool is imitated on the work surface and this ideal SR is largely reliant on cutting feed. That means for a larger feed the mean roughness value is more as associated to the lesser feed. It would be noted that the size of chips cross-sectional area has a great influence on surface finish. Surface finish is poor for large cuts which is required from significant of great tool life and power consumption. Larger feed is more detrimental to surface finish than a larger depth of cut.

For very high cutting speeds the probabilities of built up edge decreases thus SR also expected to decrease, while when cutting speed is small built-up formation of chips would increase the SR.

1.4 Carbon Steel

Carbon steels are steels with carbon content up to 2.1% by weight. Carbon steel is a metal alloy, a mixture of two elements that are iron and carbon, where other elements are present in magnitudes too small to influence the properties. The only other elements permissible in plain-carbon steel are: manganese (1.65% max), silicon (0.60% max), and copper (0.60% max). It is by far the most frequent used steel. As carbon content increases the metal turn into harder and tougher but less ductile and more problematic to weld. Higher carbon content drops steel's melting point and its temperature resistance in general. Carbon steels may be further classified into 3 major groups: low carbon steel, medium carbon steel and high carbon steel.

1.4.1 Low Carbon Steel

Low carbon steel, also known as mild steel, contains 0.05 % to 0.26 % of carbon with up to 0.4% manganese content (e.g. AISI 1018, AISI 1020 steel). It is now the most general form of steel because its value is comparatively low while it offers material properties that are suitable for many applications. These steels are ductile and have properties similar to iron. They are cheap, but engineering applications are limited to non-critical components and general paneling and fabrication work. These steels cannot be efficiently heat treated. So, there are typically no problems related with heat affected zones (HAZ) in welding process. The surface properties can be improved by carburizing and then heat treating the carbon-rich surface. High ductility characteristic results in poor machinability.

1.4.2 Medium Carbon Steel

Medium carbon steel contains 0.29 % to 0.54 % of carbon content with 0.60 to 1.65% manganese content (e.g. AISI 1040, AISI 1045 steel). These steels are highly vulnerable to thermal treatments and work hardening. They effortlessly flame harden and can be treated and functioned to yield great tensile strengths provided that low ductility can be endured. It stabilities ductility and strength and has decent wear resistance. The corrosion resistance of these steels is similar to low carbon steel, although small additions of copper can lead to major improvements when weathering performance is important. Medium carbon steels which are still cheap and command mass market. They are general purpose but can be specified for use in stressed applications such as rails and rail products, couplings, crankshafts, axles, bolts, rods, gears, forgings, tubes, plates and constructional steels.

1.4.3 High Carbon Steel

High carbon steel contains 0.55 % to 0.95 % carbon content with 0.30 to 0.90% manganese content (e.g. AISI 1086, AISI 1090). Cold working is not achievable with any of these steels, as they fracture at very low elongation. They are extremely sensitive to thermal treatments. Machinability is good, although their hardness needs machining in the normalized condition.

Welding is not suggested and these steels must not be exposed to impact loading. They are normally used for components that require high hardness such as cutting tools, blades, springs and high-strength wires.

1.5 Taguchi Method

Taguchi's parametric design is the efficient tool for robust design it proposes an easy and organized qualitative optimal design to a relatively low cost. The Taguchi method of off-line (Engineering) quality control includes all stages of product/process development. However the significant element for attaining high quality at low cost is DOE. Taguchi's (DOE) method is used to observe the consequence of cutting parameters like cutting speed, feed, and depth of cut on SR of mild steel work material while machining with carbide tool and to obtain an optimal setting of these parameters that may result in good surface finish [4]. The idea of Taguchi is broadly applicable. He suggested that engineering optimization of a process or product should be carried out in a three-step approach, i.e., system design, parameter design, and tolerance design.

1.5.1 System Design

In system design, the engineer applies scientific and engineering knowledge to create a basic functional prototype design, this design includes the product design stage and the process design stage. In the product design stage, the choice of materials, components, uncertain product parameter values, etc., are involved. As to the process design stage, the evaluation of processing sequences, the selections of production equipment, provisional process parameter values, etc., are involved. Since system design is an initial functional design, it may be far from optimum in terms of quality and cost. This is design at the conceptual level, involving creativity and innovation.

1.5.2 Parameter Design

The purpose of the parameter design is to enhance the settings of the process parameter values for refining performance features and to identify the product parameter values under the ideal process parameter values. In addition, it is likely that the ideal process parameter values attained from the parameter design are indifferent to the variation of environmental conditions and other noise factors. Therefore, the parameter design is the significant step in the Taguchi method to attaining great quality without increasing cost. Basically, traditional parameter design, established by Fisher, is complicated and not easy to use. Especially, a great number of experiments have to be carried out when the number of the process parameters increases. To solve this task, the Taguchi method uses an extraordinary design of orthogonal arrays to study the whole parameter space with a small number of experiments only. A loss function is then expressed to compute the abnormality between the experimental value and the desired value. Taguchi suggests the employment of the loss function to compute the performance characteristic contrary from the anticipated value. The significance of the loss function is further altered into a signal-to-noise (S/N) ratio η; usually there are three types of the performance.

There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems;

(I) SMALLER-THE-BETTER:

$n = -10 \ Log_{10}$ [mean of sum of squares of measured data]

This is usually the chosen S/N ratio for all undesirable characteristics like " defects " etc. for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value is defined (like maximum purity is 100% or maximum Tc is 92K or minimum time for making a telephone connection is 1 sec) then the difference between measured data and ideal value is expected to be as small as possible. The generic form of S/N ratio then becomes,

$n = -10 \ Log_{10}$ [mean of sum of squares of {measured - ideal}]

(II) LARGER-THE-BETTER :

$n = -10 \ Log_{10}$ [mean of sum squares of reciprocal of measured data]

This case has been converted to SMALLER-THE-BETTER by taking the reciprocals of measured data and then taking the S/N ratio as in the smaller-the-better case.

(III) NOMINAL-THE-BEST :

$$n = 10 \ Log_{10} \ \frac{\text{Square of mean}}{\text{variance}}$$

characteristic in the assessment of the S/N ratio, that is, the lower-the-better, the higher-the-better, and the nominal- the-better. The S/N ratio for each level of process parameters is calculated based on the S/N assessment [5].

The Full Factorial Design requires a large number of experiments to be carried out as stated above. It becomes laborious and complex, if the number of factors increase. To overcome this problem Taguchi suggested a specially designed method called the use of orthogonal array to study the entire parameter space with lesser number of experiments to be conducted. Taguchi thus, recommends the use of the loss function to measure the performance characteristics that are deviating from the desired target value. The value of this loss function is further transformed into signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristics to analyse the S/N ratio. They are: nominal-the-best, larger-the-better, and smaller-the-better. Involved in Taguchi Method The use of Taguchi's parameter design involves the following steps

- Identify the main function and its side effects.
- Identify the noise factors, testing condition and quality characteristics.
- Identify the objective function to be optimized.
- Identify the control factors and their levels.
- Select a suitable Orthogonal Array and construct the Matrix.
- Conduct the Matrix experiment. .
- Examine the data; predict the optimum control factor levels and its performance.
- .Conduct the verification experiment.

1.5.3 Tolerance Design

With a positively accomplished parameter design, and an understanding of the consequence that the several parameters have on performance, resources can be focused on reducing and controlling deviation in the critical few dimensions.

1.6 Design of Experiment

Design of experiments is a powerful analysis tool for modelling and analysing the influence of process variables over some specific variable which is an unknown function of these process variables [6]. The DOE is considered as one of the most widespread approach in product/process developments. It is a statistical approach that attempts to provide a predictive knowledge of a complex, multi-variable process with few trials.

1.7 Full Factorial Design

A full factorial experiment is an experiment whose design involves two or more factors, each with a distinct possible level and whose experimental units take all probable combinations of all those levels among all such factors. Such an experiment permits studying the consequence of each factor on the response variable, as well as on the effects of connections between factors on the response variable. A general experimental design is the one with all input factors set at two levels each. If there are k factors each at 2 levels; a full factorial design has 2^k runs. Thus for 3 factors at three levels it would take 27 trial runs.

Steps of Taguchi method are as follows [7]:

i. Identification of key function, side effects and failure mode.
ii. Identification of noise factor, testing condition and quality characteristics
iii. Identification of the key function to be optimized.
iv. Identification of the governor factor and their levels.
v. Selection of orthogonal array and matrix experiment.
vi. Conducting the matrix experiment.
vii. Analyzing the data, forecast of the optimal level and performance.
viii. Executing the verification experiment and scheduling future action

1.8 ANOVA

Since there are a great number of variables monitoring the process, some mathematical models are required to signify the process. However, these models are to be established using only the important parameters influencing the process rather than including all the parameters. In order to achieve this, statistical analysis of the experimental results will have to be processed using the ANOVA which is a computational technique that permits the estimation of the comparative assistances of each of the control factors to the overall measured response.

ANOVA can be beneficial for defining impact of any given input parameter from a series of experimental results by DOE for machining process and it can be used to interpret experimental data. ANOVA is an assembly of statistical models, and their related procedures, in which the monitored variance in a particular variable is partitioned into components attributable to different sources of variation. In its easiest form, ANOVA offers a statistical test of whether or not the means of several groups are all equal, and therefore simplifies t-test to more than two groups. ANOVA is used in the study of relative experiments, those in which only the alteration in outcomes is of interest. The statistical implication of the experiment is determined by a ratio of two variances. This ratio is independent of several possible modifications to the experimental observations: Adding or multiplying a constant to all observations does not alter consequence. So ANOVA statistical consequence results are independent of constant bias and scaling errors as well as the units used in expressing observations.

1.9 MOTIF-method

The MOTIF-method is a structure for the assessment of the primary profile and established on the envelope system and is appropriate as an alternative to the mean line system. The MOTIF-method controls the upper points of the surface profile, which have an importance for the functional behavior.

SR and waviness can be evaluated directly based on the diagram of the unfiltered profile. SR and waviness measurements in industry are globally widespread accomplished by stylus instruments. To isolated SR from waviness, the mean line system uses electronic filtering. The MOTIF-method (ISO 12085) offers a substitute assessment to isolated SR and waviness by means of unfiltered profiles. The MOTIF-method is a graphical assessment with the complete explanation of roughness and waviness with merely 7 parameters and the assessment based on the upper envelope line. The MOTIF-method finds out within these limits the horizontal and vertical properties of the vital profile irregularities without removal of important profile points. It is very well matched for technical inquiries on unknown surfaces and processes, functions related to the envelope of the surfaces and profiles with very close wavelengths for roughness and waviness [9].

CHAPTER 2

LITERATURE REVIEW

A considerable number of studies have investigated the general effects of the speed, feed, and depth of cut, nose radius, forces and others parameters on the surface roughness. These studies have been briefly discussed for the variations observed experimentally.

Sharma et al.(2015) *stated that* there is a development of new materials every day and for each new material, we need economical and efficient machining. Taguchi is one of the good method for optimization of various machining parameters that reduces number of experiments. The objective of this paper is to develop the Taguchi optimization method using Lubricant for high material removal rate in terms of process parameters, in turning of EN-353 steel, considering the process parameters as cutting speed, feed rate, depth of cut, type of tool. A series of turning experiments were performed to measure material removal rate. Taguchi orthogonal arrays, signal-to-noise(S/N) ratio are used to find the optimal levels and the effect of the process parameters on material removal rate[1]

Hascalik and Caydas([2008) *stated that* worked on the development of surface roughness prediction models for turning EN 24T steel (290 BHN) utilizing response surface methodology. A factorial design technique has been used to study the effects of the main cutting parameters such as cutting speed, feed, and depth of cut, on surface roughness. The tests have been carried out using uncoated carbide inserts without any cutting fluid. A first-order prediction model within the speed range of 36-117 m min^{-1} a second-order model covering the speed range of 28-150 m min^{-1} have been presented. The results reveal that response surface methodology combined with factorial design of experiments is a better alternative to the traditional one variable-at-a-time approach for studying the effects of cutting variables on responses such as surface roughness and tool life. This significantly reduces the total number of experiments required. The results have revealed that the effect of feed is much more pronounced than the effects of cutting speed and depth of cut, on the surface roughness. However, a higher cutting speed improves the surface finish. [2]

Koli et al. (2016) states that the Taguchi method, a powerful tool to design optimization for quality, is used to find the optimal cutting parameters for turning operations. An orthogonal array, the signal-to-noise (S:N) ratio, and the analysis of variance (ANOVA) are employed to investigate the cutting characteristics of S45C steel bars using tungsten carbide cutting tools. The Taguchi method provides a systematic and efficient methodology for the design optimization of the cutting parameters with far less effect than would be required for most optimization techniques. The confirmation experiments were conducted to verify the optimal cutting parameters. The improvement of tool life and surface roughness from the initial cutting parameters to the optimal cutting parameters is about 250%. [3]

Lu.c.(2008)uses Taguchi method to find the optimal cutting parameters for surface roughness in turning. The orthogonal array, the signal-to-noise ratio, and analysis of variance are employed to study the performance characteristics in turning operations of AISI 1030 steel bars using TiN coated tools. Three cutting parameters namely, insert radius, feed rate, and depth of cut, are optimized with considerations of surface roughness. The experimental results demonstrate that the insert radius and feed rate are the main parameters among the three controllable factors (insert radius, feed rate and depth of cut) that influence the surface roughness in turning AISI 1030 carbon steel. In turning, use of greater insert radius (1.2 mm), low feed rate (0.15 mm/rev) and low depth of cut (0.5 mm) are recommended to obtain better surface roughness for the specific test range. The improvement of surface roughness form initial cutting parameters to the optimal cutting parameters is about 33.5%. [4]

Chandraker(2015)stated that focuses on optimizing turning parameters based on the Taguchi method to minimize surface roughness (Ra and Rz). Experiments have been conducted using the L9 orthogonal array in a CNC turning machine. Dry turning tests are carried out on hardened AISI 4140 (51 HRC) with coated carbide cutting tools. Each experiment is repeated three times and each test uses a new cutting insert to ensure accurate readings of the surface roughness. The statistical methods of signal to noise ratio (SNR) and the analysis of variance (ANOVA) are applied to investigate effects of cutting speed, feed rate and depth of cut on surface roughness. Results of this study indicate that the feed rate has the most significant effect on Ra and Rz. Optimum cutting conditions which correspond for the smaller surface roughness in hard turning method were found to be 120 m/min for the cutting speed, 0.18 mm/rev for the feed rate and 0.4 mm for the depth of cut. [5]

Lalwani et al.(2008) the effects of cutting speed, feed rate, workpiece hardness and depth of cut on surface roughness and cutting force components in the hard turning were experimentally investigated. AISI H11 steel was hardened to (40; 45 and 50) HRC, machined using cubic boron nitride (CBN 7020 from Sandvik Company) which is essentially made of 57% CBN and 35% TiCN. Four-factor (cutting speed, feed rate, hardness and depth of cut) and three-level fractional experiment designs completed with a statistical analysis of variance (ANOVA) were performed. Mathematical models for surface roughness and cutting force components were developed using the response surface methodology (RSM). Results show **f**eed rate and work piece hardness have major statistical influences on the surface roughness.

Lower feed rate and the high cutting speed lead to best surface roughness.[6]

Davim et al. (2008) studies the effect of cutting parameters on the surface roughness in turning of titanium alloy has been investigated using response surface methodology. The experimental studies were conducted under varying cutting speeds, feed and depths of cut. The chip formation and SEM analysis are discussed to enhance the supportive surface quality achieved in turning. The work material used for the present investigation is commercial aerospace titanium alloy (gr5) and the tool used is RCMT 10T300 –MTTT3500 round insert. Taguchi ANOVA analysis was performed. The most influencing parameter was identified as the feed. The order of importance was feed, followed by depth of cut and cutting speed. [7]

Davim et al. (2004) focused on optimizing the cutting conditions for the average surface roughness (Ra) obtained in machining of high-alloy white cast iron (Ni-Hard) at two different hardness levels (50 HRC and 62 HRC). Machining experiments were performed at the CNC lathe using ceramic and cubic boron nitride (CBN) cutting tools on Ni-Hard materials. Cutting speed, feed rate and depth of cut were chosen as the cutting parameters. Taguchi L18 orthogonal array was used to design of experiment. Optimal cutting conditions was determined using the signal-to-noise (S/N) ratio which was calculated for Ra according to the ‘‘the-smaller-the-better’’ approach. The effects of the cutting parameters and tool materials on surface roughness were evaluated by the analysis of variance. The most significant variable for Ni-Hard with 62 HRC was found the feed rate while the variable that was the most significant for Ni-Hard with 50 HRC was the cutting speed.[8]

Singh and rao (2007) develops a knowledge-based system for the prediction of surface roughness in turning process. Neural networks and fuzzy set theory are used for this purpose. Knowledge acquired from the shop floor is used to train the neural network. The trained network provides a number of data sets, which are fed to a fuzzy-set-based rule generation module. A large number of IF–THEN rules are generated, which can be reduced to a smaller set of rules by using Boolean operations. The developed rule base may be used for predicting surface roughness for given process variables as well as for the prediction of process variables for a given surface roughness. Results shows that reducing the ranges and increasing the number of training data is expected to improve the accuracy of the surface roughness. [9]

Bagci and Isik (2006) focuses on optimising the turning of raw workpieces of low-carbon steel with low cold pre-deformation to achieve acceptable surface roughness. An attempt was made to minimise the number of experimental runs and increase the reliability of experimental results. According to the presence in the additive model and according to the analysis results, the cutting speed is the most powerful control factor of the process. A higher cutting speed results in a smoother surface. [10]

Gunay and Yucel (2013) deals with the study and development of a surface roughness prediction model for machining mild steel, using Response Surface Methodology (RSM). The experimentation was carried out with TiN-coated tungsten carbide (CNMG) cutting tools, for machining mild steel work-pieces covering a wide range of machining conditions. A second order mathematical model, in terms of machining parameters, was developed for surface roughness prediction using RSM. This model gives the factor effects of the individual process parameters. An attempt has also been made to optimize the surface roughness prediction model using Genetic Algorithms (GA) to optimize the objective function. Surface quality can be greatly controlled using Genetic Algorithms.[11]

Aouici et al. (2012),stated that an abductive network is adopted to construct a prediction model for surface roughness and cutting force. This network is composed of a number of functional nodes, which are self-configured to form an optimal network hierarchy by using a predicted square error (PSE) criterion. Once the process parameters (cutting speed, feed rate and depth of cut) are given, the surface roughness and cutting force can be predicted by this network. To verify the accuracy of the abductive network, regression analysis has been adopted to develop a second prediction model for surface roughness and cutting force. Comparison of the two models indicates that the prediction model developed by the abductive network is more accurate than that by regression analysis. Critical elements that affect surface roughness are the feed rate, where increasing feed rate will increase the surface roughness value, while a regression multiplier for the surface roughness demonstrates that the cutting speed does not have a significant impact on surface roughness.[12]

Singh and Garg (2011), The performance of a multilayer tungsten carbide tool was described using response surface methodology (RSM) when turning AISI 1045 steel. Cutting tests were performed with constant depth of cut and under dry cutting conditions. The factors investigated were cutting speed, feed and the side cutting edge angle (SCEA) of the cutting edge. The main cutting force, i.e. the tangential force and surface roughness were the response variables investigated. The experimental plan was based on the face centred, central composite design (CCD). The experimental results indicate that the proposed mathematical models suggested could adequately describe the performance indicators within the limits of the factors that are being investigated. The ANOVA revealed that feed is the most significant factor influencing the response variables investigated. [13]

Choudhury and Baradie (2011) In the present study, an attempt has been made to investigate the effect of cutting parameters (cutting speed, feed rate and depth of cut) on cutting forces (feed force, thrust force and cutting force) and surface roughness in finish hard turning of MDN250 steel [equivalent to 18Ni(250) maraging steel] using coated ceramic tool. The machining experiments were conducted based on response surface methodology (RSM) and sequential approach using face centered central composite design. The results show that cutting forces and surface roughness do not vary much with experimental cutting speed in the range of 55– 93 m/min. A non-linear quadratic model best describes the variation of surface roughness with major contribution of feed rate and secondary contributions of interaction effect between feed rate and depth of cut, second order (quadratic) effect of feed rate and interaction effect between speed and depth of cut. Good surface roughness can be achieved when cutting speed and depth of cut are set nearer to their high level of the experimental range (93m/min and 0.2mm) and feed rate is at low level of the experimental range (0.04mm/rev). [14]

Asilturk et al.(1997), presents a study of the influence of cutting parameters on surface roughness in turning of glass-fibre-reinforced plastics (GFRPs). A plan of experiments was performed on controlled machining with cutting parameters prefixed in workpiece. A statistical technique, using orthogonal arrays and analysis of variance, has been employed to investigate the influence of cutting parameters on surface roughness in turning GFRPs tubes using polycrystalline diamond cutting tools. The objective was to obtain the contribution percentages of the cutting parameters (cutting velocity and feed rate) on the surface roughness in GFRPs workpiece. Results shows that with this cutting parameters (speed and feed) it was possible to obtain surfaces with 0.80-1.75mm of arithmetic average roughness (Ra) and 4.9-9.3mm of maximum peak-to-valley height (Rt/Rmax). The surface roughness (Ra and Rt/Rmax) increases with the feed rate and decreases with the cutting velocity and feed rate is the cutting parameter that has the highest physical as well statistical influence on surface roughness (Ra and Rt/Rmax) in workpiece [15].

Kopac and Sokovic (2002),stated that An experimental investigation was conducted to determine the effects of cutting conditions and tool geometry on the surface roughness in the finish hard turning of the bearing steel (AISI 52100). Mixed ceramic inserts made up of aluminium oxide and titanium carbonitride (SNGA), having different nose radius and different effective rake angles, were used as the cutting tools. Mathematical models for the surface roughness were developed by using the response surface methodology. The results also indicate that feed is the dominant factor affecting the surface roughness, followed by the nose radius, cutting velocity and effective rake angle [16].

Basavarajappa et al. (***2008),****stated that* In this study, the effect and optimization of machining parameters on surface roughness and tool life in a turning operation was investigated by using the Taguchi method. The experimental studies were conducted under varying cutting speeds, feed rates, and depths of cut. An orthogonal array, the signal-to-noise (S/N) ratio, and the analysis of variance (ANOVA) were employed to the study the performance characteristics in the turning of commercial Ti-6Al-4V alloy using CNMG 120408-883 insert cutting tools. Results show that the feed rate parameter is the main factor that has the highest importance on the surface roughness and this factor is about 1.72 times more important than the second ranking factor (depth of cut) whereas the cutting speed does not seem to have much of an influence on the surface roughness [17]

Davim and Resis (2005), state that In this study, machining variables such as cutting forces and surface roughness are measured during turning at different cutting parameters such as approaching angle, speed, feed and depth of cut. The data obtained by experimentation is analyzed and used to construct model using neural networks. The model obtained is then tested with the experimental data and results are indicated. Surface roughness (Ra) is positively influenced with feed and it shows negative trend with approaching angle, speed and depth of cut. The neural network model for cutting force Ra could predict with moderate accuracy [18]

Bagawade (2012), Surface finish is one of the prime requirements of customers for machined parts. The present paper presents an experimental study to investigate the effects of cutting parameters like spindle speed, feed and depth of cut on surface finish and material removal rate on EN-8. Taguchi methodology has been applied to optimize cutting parameters. The results showed that the spindle speed (the most significant factor) contributed 63.90%, depth of cut (second most significant factor) contributed only 11.32% and feed rate contribution was least with 8.33% for Ra. The contribution for feed and RPM was 60.91% and 29.83%.whereas the depth of cut contributed only 7.82% for material removal rate. It was concluded that interesting to note that spindle speed and depth of cut an approximate decreasing trend. The feed has the variable effect on surface roughness [19]

Lalwani et al. (2008), stated that Choice of optimized cutting parameters is very important to control the required surface quality. The focus of this study is the collection and analysis of surface roughness and tool vibration data generated by lathe dry turning of mild carbon steel samples at different levels of speed, feed, depth of cut, tool nose radius, tool length and workpiece length. A full factorial experimental design (288 experiments) that allows to consider the three-level interactions between the independent variables has been conducted. The analogy of the effect of cutting parameters between tool dynamic forces and surface roughness is also investigated. The results show that second order interactions between cutting speed and tool nose radius, along with third-order interaction between feed rate, cutting speed and depth of cut are the factors with the greatest influence on surface roughness and tool dynamic forces in this type of operation and parameter levels studied. The analysis of variance revealed that the best surface roughness condition is achieved at a low feed rate (less than 0.35 mm/rev), a large tool nose radius (1.59 mm) and a high cutting speed (265 m/min and above). The results also show that the depth of cut has not a significant effect on surface roughness, except when operating within the built-up edge range. In these cases, built-up edge formation deteriorates surface roughness and increases dynamic forces acting on the tool. The effect of built-up edge formation on surface roughness can be minimized by increasing depth of cut and increasing tool vibration [20]

Ranganath M.S. et al. (2013), stated that investigates the parameters affecting the roughness of surfaces produced during the turning process for the material Aluminium 6061. The surface roughness is considered as quality characteristic while the process parameters considered are speed, feed and depth of cut .Design of experiments were conducted for the analysis of the influence of the turning parameters on the surface roughness by using Taguchi design. The results of the machining experiments for Aluminium 6061 were used to characterize the main factors affecting surface roughness by the Analysis of Variance (ANOVA) method. The ANOVA and F-test revealed that the feed is dominant parameter followed by depth of cut and speed for surface roughness.

The optimal combination process parameter for minimum surface roughness is obtained at 2100 rpm, 0.1 mm/rev and 0.2mm. A regression model is developed for surface roughness which is reasonably accurate and can be used of prediction within limits. Taguchi gives systematic simple approach and efficient method for the optimum operating conditions [21]

CHAPTER 3

EXPERIMENTAL SET UP

In this chapter, we would discuss the experimental set up, machine used, its limitations, advantages, measuring instrument, tooling used on the machine.

3.1 Conventional lathe

The lathe is a very versatile and important machine to know how to operate. This machine rotates a cylindrical object against a tool that the individual controls. The lathe is the forerunner of all machine tools. The work is held and rotated on its axis while the cutting tool is advanced along the line of a desired cut. The lathe is one of the most versatile machine tools used in industry. With suitable attachments, the lather may be used for turning, tapering, form turning, screw cutting, facing, dulling, boring, spinning, grinding, polishing operation.

Fig. 3.1 Lathe Machine

Cutting operations are performed with a cutting tool fed either parallel or at right angles to the axis of the work. The cutting tool may also be fed at an angle, relative to the axis of the work, for machining taper and angles. On a lathe, the tailstock does not rotate. Instead, the spindle that holds the stock rotates. Collets, centres, three jaw chucks, and other work-holding attachments can all be held in spindle. The tailstock can hold tools for drilling, threading, reaming, or cutting tapers. Additionally, it can support the end of the workpiece using a centre and can be adjusted to adapt to different workpiece lengths.

3.2 Working Principle

The lathe is a machine tool which holds the workpiece between two rigid and strong supports called centres or in a chuck or face plate which revolves. The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work. The normal cutting operations are performed with the cutting tool fed either parallel or at right angles to the axis of the work.

The cutting tool may also be fed at an angle relative to the axis of work for machining tapers and angles.

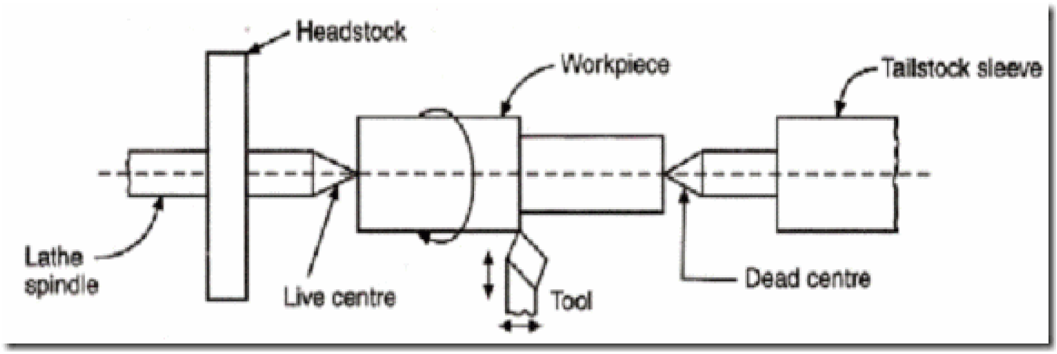

Fig. 3.2 Working Principle of lathe machine

3.3 Construction

The main parts of the lathe are the bed, headstock, quick changing gear box, carriage and tailstock.

1. **Bed**: The bed is a heavy, rugged casting in which are mounted the working parts of the lathe. It carries the headstock and tail stock for supporting the workpiece and provides a base for the movement of carriage assembly which carries the tool.

2. **Legs**: The legs carry the entire load of machine and are firmly secured to floor by foundation bolts.

3. **Headstock**: The headstock is clamped on the left hand side of the bed and it serves as housing for the driving pulleys, back gears, headstock spindle, live centre and the feed reverse gear. The headstock spindle is a hollow cylindrical shaft that provides a drive from the motor to work holding devices.

4. **Gear Box**: The quick-change gear-box is placed below the headstock and contains a number of different sized gears.

5. **Carriage**: The carriage is located between the headstock and tailstock and serves the purpose of supporting, guiding and feeding the tool against the job during operation. The main parts of carriage are:

a). **The saddle** is an H-shaped casting mounted on the top of lathe ways. It provides support to cross-slide, compound rest and tool post.

b). **The cross slide** is mounted on the top of saddle, and it provides a mounted or automatic cross movement for the cutting tool.

c). **The compound rest** is fitted on the top of cross slide and is used to support the tool post and the cutting tool.

d). **The tool post** is mounted on the compound rest, and it rigidly clamps the cutting tool or tool holder at the proper height relative to the work centre line.

e). **The apron** is fastened to the saddle and it houses the gears, clutches and levers required to move the carriage or cross slide. The engagement of split nut lever and the automatic feed lever at the same time is prevented she carriage along the lathe bed.

6. **Tailstock**: The tailstock is a movable casting located opposite the headstock on the ways of the bed. The tailstock can slide along the bed to accommodate different lengths of workpiece between the centers. A tailstock clamp is provided to lock the tailstock at any desired position. The tailstock spindle has an internal taper to hold the dead centre and the tapered shank tools such as reamers and drills.

3.4 Lathe Tool Dynamometer

This is a strain Gauge Type two/three component Lathe Tool Dynamometer designed to measure vertical & horizontal/(radial force in case of three component) forces on tool during cutting process. The unit consists of a mechanical sensing unit or tool holder and digital force indicator. With this dynamometer, students can study the change in these forces due to change in speed, feed and depth of cut. A machine-tool dynamometer is a multi-component dynamometer that is used to measure forces during the use of the machine tool. Empirical calculations of these forces can be cross-checked and verified experimentally using these machine tool dynamometers.

Fig. 3.3 Lathe Tool Dynamometer

With advances in technology, machine-tool dynamometers are increasingly used for the accurate measurement of forces and for optimizing the machining process. These multi-component forces are measured as an individual component force in each co-ordinate, depending on the coordinate system used. The forces during machining are dependent on depth of cut, feed rate, cutting speed, tool material and geometry, material of the work piece and other factors such as use of lubrication/cooling during machining

Specifications :-

Mechanical Sensing Unit with Tool Holder and Tool with strain Gauges mounted on it.

Digital Force Indicator - two/three channel, to read both forces simultaneously.

Balancing Potentiometer for initial balancing Range - 0 to 200 Kg, least count - 1 Kg.

3.5 Surface Roughness Measuring Instrument

The Surtronic 3+ is a movable, self-contained for the measurement of surface texture and is appropriate for use in both the workshop and laboratory. Parameters accessible for surface texture evaluation are: Ra, Rq, Rz (DIN), Ry and Sm.

The parameters evaluations and other functions of the instrument are microprocessor based. The measurement results are displaced on an LCD screen and can be output to a voluntary printer or another computer for further results.

The instrument is normally powered by an alkaline non-rechargeable battery. If preferred, a Ni-Cad rechargeable battery can be used [28][31].

Fig. 3.4 (Surface roughness measurement apparatus)

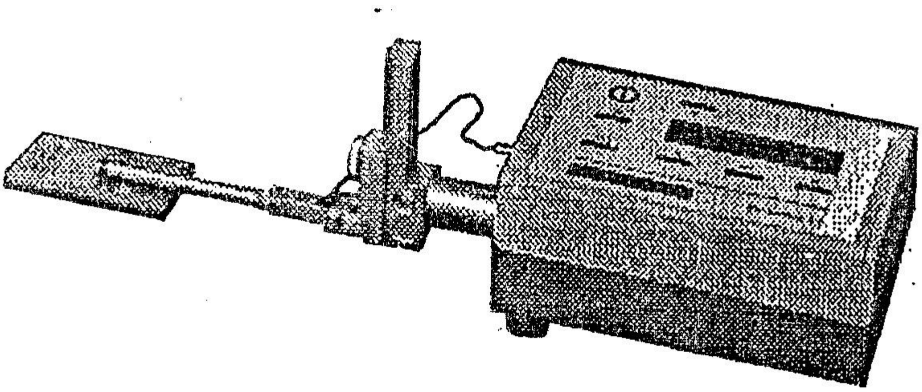

Fig. 3.5 Surface roughness measurement apparatus (Referred from Instrument Manual)

3.5.1 Display-Transverse Unit

The top panel of the display-traverse unit carries a membrane type control panel and a liquid crystal display. The unit houses the electronics for controlling the measurement sequence, calculating the measurement data and outputting the results to the display, or to the RS232 port for use with a printer (when included) or to a computer for further analysis.

The unit also comprises a drive motor which traverses the pickup across the surface to be measured. The measuring stroke always starts from the extreme outward positions.

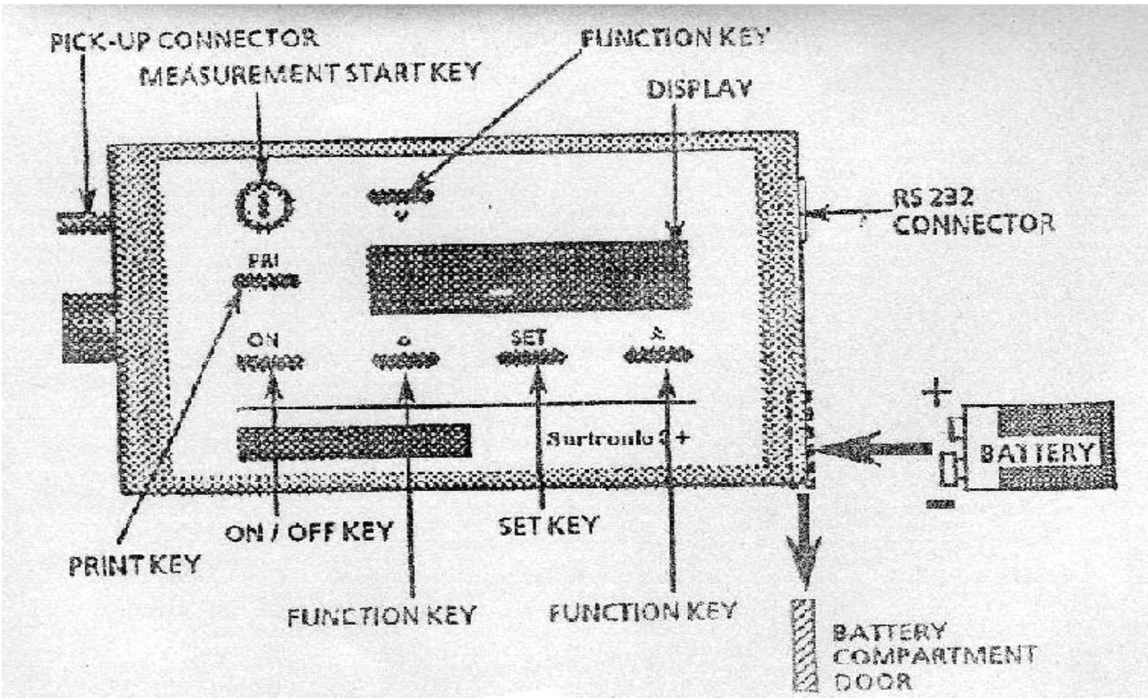

Fig. 3.6 Display Transverse Unit (Referred from Instrument Manual)

At the conclusion of the measurement the pickup returns to this position prepared for the next measurement. The traverse length is determined from selections of cut-off (Lc) or length (Ln). Taylor Hobson Surtronic 3+ instrument available has a pickup with a skid which is used to travel automatically through a drive motor. Thus such travel would at least require a distance of at least 10 mm. Thus we require appropriate surface travel distance on turned work piece. These dimensions were engaged so as to keep travel the stylus on the best surface as the cutting could improper at the starting or at the end. In this way the error in measurement could also be reduced and there are less chance of measuring the wrong side values.

3.5.2 Pick-Up Mounting Components

The pick-up is fastened to the drive shaft by the following means.

3.5.3 Mounting Bracket

This is fastened to the drive shaft by means of a knurled knob. Although normally used upright, it can be turned to angle the pick-up or to take it off the centre line. It can also be mounted sideways on the drive shaft, when the right-angle pick-up is in use.

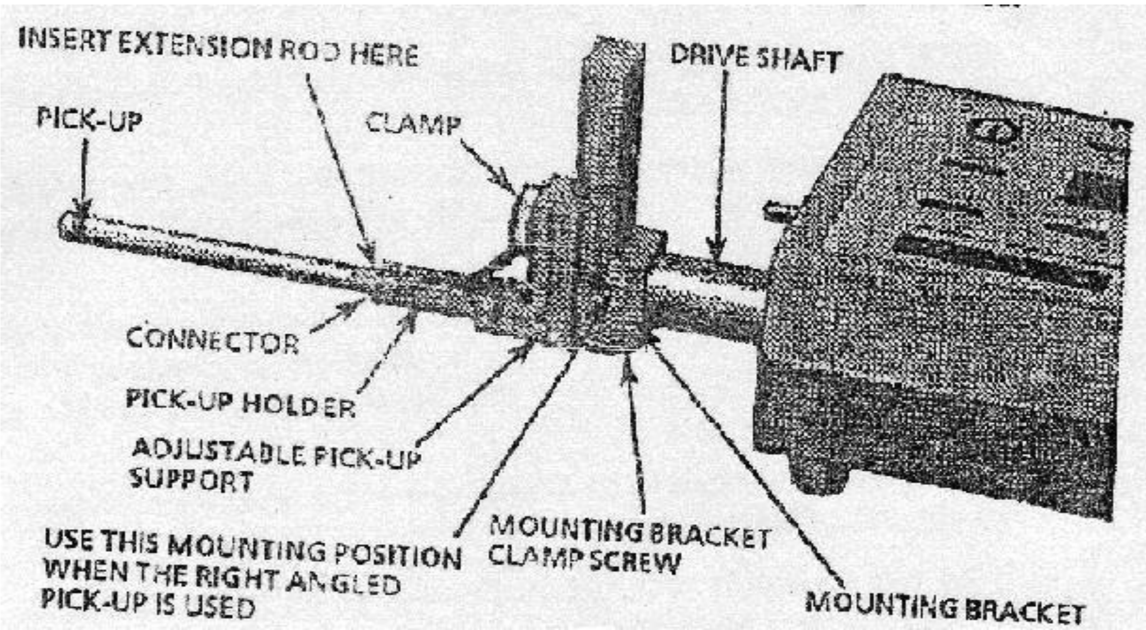

Fig. 3.7 Mounting Bracket (Referred from Instrument Manual)

3.5.4 Adjustable Support

This can be clamped at any positions on the slide of the mounting bracket to provide pick-up height adjustment.

3.5.5 Pick-up Holder

This fits into the crutch of the pick-up support and is held in place by a spring plunger.

3.5.6 Connector

The connector of the pick-up lead is screwed into the end of pick-up and is then inserted into the end of the pick-up holder, with the lead coming out through the slot in the holder. It is advisable to connect the lead to the display-traverse unit first and then to the pick-up. When the extension rod is used, the short pick-up is not required and the end of the rod itself is inserted into the holder.

3.5.7 DIP switch settings

The instrument default settings, when powering up with a new battery, are set via DIP switches housed inside the display-traverse unit. The selections can be altered by menu/pushbuttons operations. The DIP switches are accessed by unscrewing the three feet from the base of the display-traverse unit, then removing the screws which were partly covered by the feet.

3.5.8 Pick-up

The pickup is a variable reluctance type transducer which is supported on the surface to be measured by a skid, a curved support projecting from the underside of the pickup in the vicinity of the stylus. As the pickup traverses across the surface, movements of the stylus relative to the skid are detected and are converted into a proportional electrical signal. The radius of curvature of the skid is much greater than the roughness spacing. This enables it to ride across the surface almost unaffected by the roughness, and provides a datum representing the general form of the surface. Even so, where the waviness is widely spaced it will be necessary to use the pickup with shoe, in conjunction with the 2.5mm (0.1 in) cut-off.

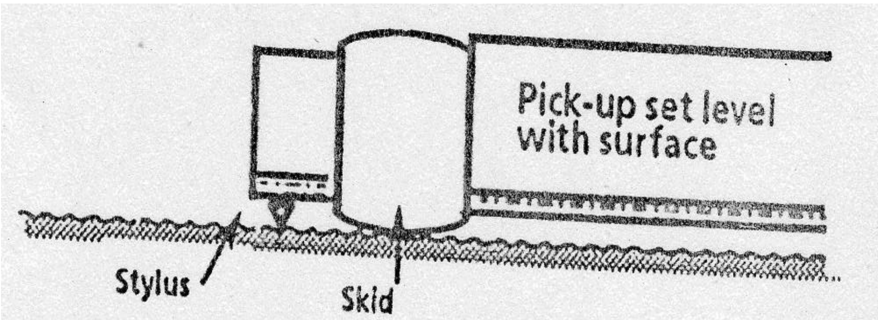

Fig. 3.8 Pick-up (Referred from Instrument Manual)

TABLE 3.1 Surtronic 3+ Specifications

Battery	Alkaline: Minimum 600 Measurements of 4mm Measurements Lengths. Ni-Cad: Minimum 200 Measurement of 4mm Length Size: 6 LR 61 (USA/Japan), Fixed Battery External Charger (Ni-Cad Only) 110/240V, 50/60 Hz
Traverse Unit	Traverse Speed: 1mm/Sec
Measurement	Metric/Inch Preset by DIP-Switch
Cut-Off Values	0.25mm, 0.8mm, and 2.50mm
Traverse Length	1, 3, 5, 10, Or 25.4 + 0.2mm At 0.8mm Cut-Off.
Display	LCD-Matrix. 2lines * 16 Characters
Keyboard	Membrane Switch Panel Tactile
Filters	Digital Gauss Filters or 2CR Filter (ISO) Selectable By DIPSwitch.
Parameters	Ra, Rq, Rz (DIN), Ry and Sm.
Calculations Time	Less Than Reversal Time Or 2 Sec Which Ever Is The Longer.

3.6 Experimental Procedure

Experiment was conducted on a lathe machine with work piece of mild steel (EN-353), 40mm diameter and 300 mm long mounted between 3-jaw chuck and tailstock. Initially rough turning is done on lathe machine to remove scaling that is present on the surface of mild steel (EN-353). The full factorial 27 experiments were conducted according to the Taguchi DOE and surface is measured by using instrument Surtronic 3+. With the help of Minitab software, Taguchi, ANOVA and Regression analysis are applied and results are obtained. Lathe tool dynamometer instrument is used for the measurement of these three forces, cutting forces (F_c), feed forces (F_d), thrust forces (F_t). and resultant of all these forces

Fig. 3.9 Machined parts (mild steel EN-353)

3.6.1 Work piece material

The cutting performance tests were performed on EN-353 steel in the form of round bars of dimension 300 mm in length and 45 mm in diameter. Its chemical composition was obtained by spectral analysis and summarized in Table 1. Turning operation was carried out on Conventional lathe. The lathe equipped with continuously variable spindle speed from 289to 1000 rpm, and 20 kW motor drive was used for machining tests.

Table 3.2 Work piece material

Table 1
Chemical composition of EN-353 carbon steel, %weight

Element	C	Mn	Si	P	S	Cr	Ni
Percentage	0.181	0.67	0.23	0.021	0.013	0.81	1.1

Lathe was available for cantering and lathe machine is used for turning the work piece. The chuck holding the work piece was self-cantering type. Material was selected to ensure consistency of the alloy, which is a Mild Steel (EN-353) made in the form of bars with the size of diameter 40mm and 300mm length so as to fit under the chuck. To more carefully replicate typical finish turning processes and to evade unnecessary vibrations due to work piece dimensional inaccuracies and defects, each work piece was rough-cut or rough-turning is done just prior to the measured finish cut.

3.7 Steel Properties

En 353 steel has a carbon content of 0.17% and the commonest form of steel as it provides material properties that are acceptable for several automobile applications such as significant duty gear, shaft, pinion, camshafts and gudgeon pins. It's neither outwardly brittle nor ductile due to its lower carbon content and lower hardness. Because the carbon content will increase, the metal becomes more durable and stronger.

3.7.1 Physical Properties

Table3.31Physical Properties

Thermal Conductivity at °C	20	350	700
W/(m*K)	11.3	13.3	14.5

Acceptable for many automobile applications such as heavy duty gear, shaft, pinion, camshafts, gudgeon pins and Machining components.

3.7.2 Cutting Tool Material

Fig. 3.10 Carbide tool material (CNMG 120408-THM-F)

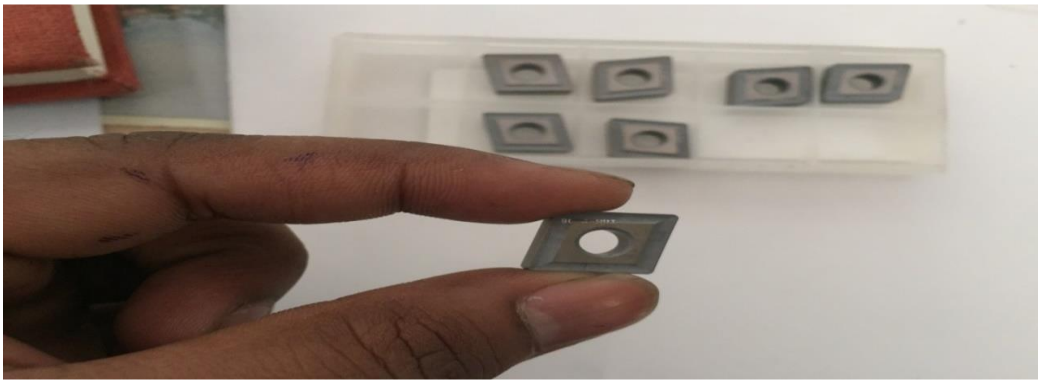

Fig. 3.11 (Carbide tool material with different geometry)

The cutting tool which is used for the present work was a carbide tip-CNMG 120408-THMF. The fundamental properties of carbide tools have great hardness over a wide range of temperature ; are very stiff (Young's modulus is nearly three times that of steel); exhibit no plastic flow (yield point) even on experiencing stresses of the order of 33300 kg/cm^2, have low thermal expansion compared with steel ; relatively high thermal conductivity: and a strong tendency to form pressure weld at low cutting speed, these are weak in tension than in compression. Their high hardness at elevated temperature enable them to be used at much faster cutting speed (3 to 4 m/sec with mild steel) superior hot hardness and wear resistance.

These can retain cutting hardness upto 700^{o}C and have high wear resistance.

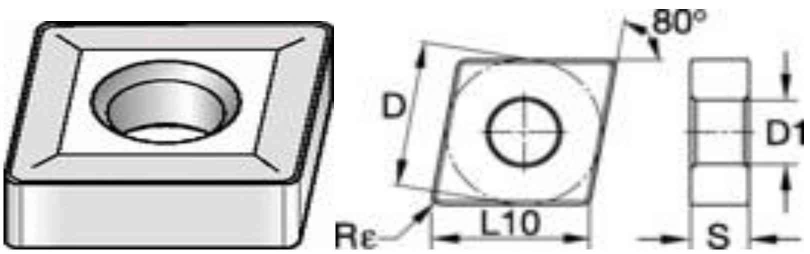

Fig. 3.12 Carbide tool specification with different coating and grades

ISO catalog number	ANSI catalog number	Grade	D (mm)	L10 (mm)	S (mm)	Rε (mm)	D1 (mm)
CNMG 120408	CNMG432	THM-F	12,70	12,90	4,76	0,8	5,16

TABLE 3.4 Carbide Tool Specification

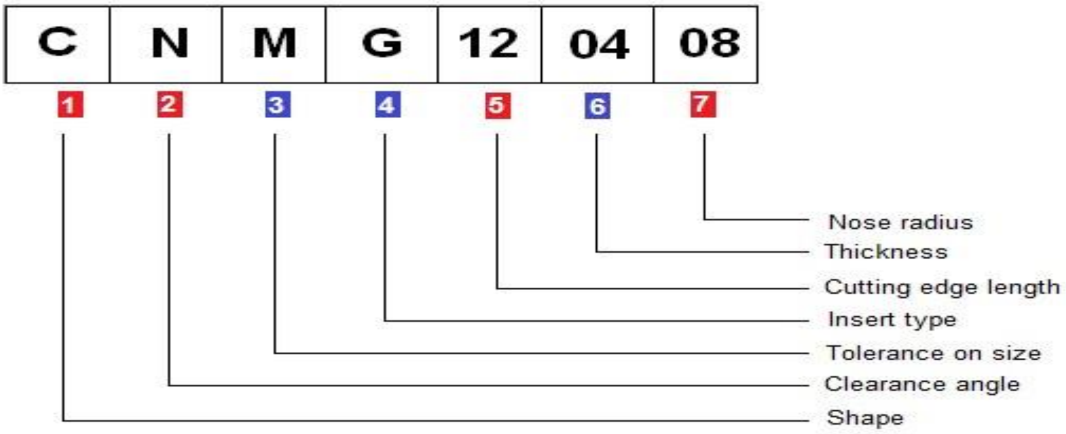

Fig. 3.13 Carbide tool insert-ISO nomenclature

3.8 Measurement of Surface Roughness

Inspection and calculation of SR of machined work pieces can be carried out by means of different measurement techniques. These methods can be ranked into the following classes:

- Direct measurement methods
- Comparison based techniques
- Non-contact methods

3.8.1 Direct Measurement Methods

Direct methods access surface finish by means of stylus type devices. Measurements are achieved using a stylus drawn along the surface to be measured. The stylus motion perpendicular to the surface is registered. This registered profile is then used to compute the roughness parameters. The parameter Ra is used here.

$$R_a = \frac{1}{L}\int_0^L |Y(x)|dx,$$

where
R_a = the arithmetic average deviation from the mean line
L= the sampling length
Y= the ordinate of the profile curve

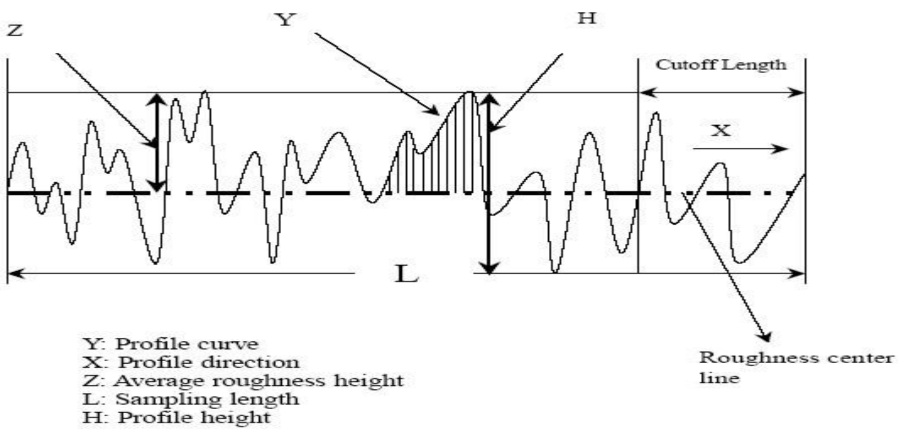

Fig. 3.14 Measurement of SR by Stylus [5]

3.8.2 Comparison Based Techniques

Comparison techniques use specimens of SR produced by the same process, material and machining parameters as the surface to be compared. Visual and tactile senses are used to compare a specimen with a surface of known surface finish. This method is useful for SR Ra>1.6 micron.

3.8.3 Non-Contact Methods

In it a rough surface is brightened by a monochromatic plane wave with an angle of incidence with respect to the normal to the surface. The photo sensor of a camera placed in the focal plane of a fourier lens is used for recording speckle patterns. Then the SR can be defined and calculated. In these experiments direct measurement technique has been used i.e. stylus type SR meter was used to calculate the SR of the specimen. There were two main reasons behind choosing stylus type SR; one is its easy obtainability and other is the ease with which it can be functioned. The instrument used in these experiments is a product of precision devices.

3.9 Factors and their Levels

The factors and their levels have been selected on the basis of tool, work piece material, machine parameters and by studying different research papers and data hand books. Different cutting parameters and their level are shown in table:

Table 3.5 Cutting Parameters and their level

Symbol	**Cutting Parameters**	**Units**	**Level 1**	**Level 2**	**Level 3**
A	**Speed**	m min^{-1}	36.31	80.29	125.66
B	**Feed**	mm rev^{-1}	0.05	0.1	0.15
C	**Depth of Cut**	mm	0.6	0.9	1.2

CHAPTER 4

ANALYSIS AND RESULTS

In this chapter analysis of surface roughness and forces are done for the data obtained from the experiments done on the lathe machine.

4.1 SURFACE ROUGHNESS ANALYSIS

Table 4.1 Surface Roughness Analysis

	Diameter (mm)	RPM	Speed (m/min)	Feed (mm/rev)	Depth of cut(mm)	Ra(μm)
1	*40*	289	36.31	0.05	0.6	3.69
2	*40*	289	36.31	0.05	0.9	1.58
3	40	289	36.31	0.05	1.2	2.85
4	40	289	36.31	0.1	0.6	2.91
5	40	289	36.31	0.1	0.9	2.97
6	40	289	36.31	0.1	1.2	2.96
7	40	289	36.31	0.15	0.6	3.3
8	40	289	36.31	0.15	0.9	3.51
9	40	289	36.31	0.15	1.2	3.27
10	40	639	80.29	0.05	0.6	1.68
11	40	639	80.29	0.05	0.9	1.38
12	40	639	80.29	0.05	1.2	1.99
13	40	639	80.29	0.1	0.6	1.49
14	40	639	80.29	0.1	0.9	1.59
15	40	639	80.29	0.1	1.2	1.37
16	40	639	80.29	0.15	0.6	1.9

17	40	639	80.29	0.15	0.9	1.45
18	40	639	80.29	0.15	1.2	1.48
19	40	1000	125.66	0.05	0.6	1.19
20	40	1000	125.66	0.05	0.9	1.07
21	40	1000	125.66	0.05	1.2	0.92
22	40	1000	125.66	0.1	0.6	1.19
23	40	1000	125.66	0.1	0.9	1.25
24	40	1000	125.66	0.1	1.2	1.18
25	40	1000	125.66	0.15	0.6	1.58
26	40	1000	125.66	0.15	0.9	1.58
27	40	1000	125.66	0.15	1.2	1.3

Graphical analysis for variable surface roughness

1. Constant speed =36.31m/min, f=0.05 mm/rev, d=1.2 mm

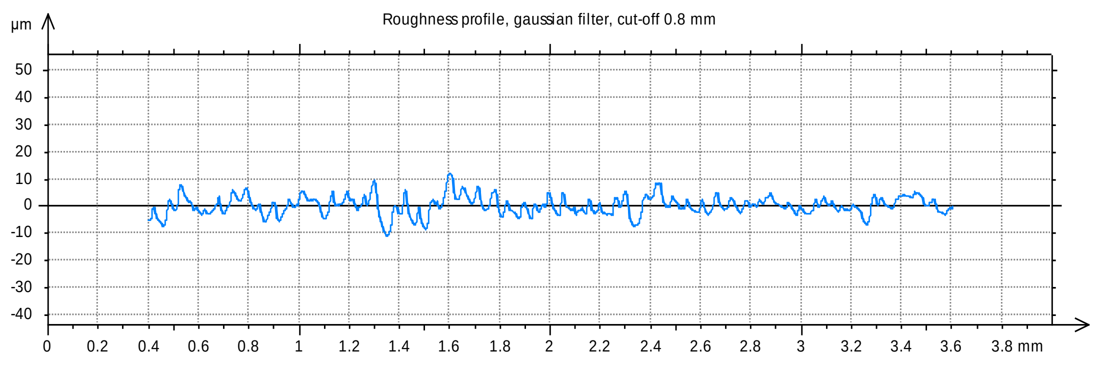

Fig. 4.1 Ra=2.85 µm profile curve of surface roughness of mild steel EN-353

Roughness profile with cut off 0.4mm An experimental verification is presented wherein a number of sample surfaces were characterized by the use of special-purpose equipment. There was significant correlation between the computed characteristics of these surfaces and their frictional properties.

2. Speed (36.31), feed (0.1), depth of cut (0.6)

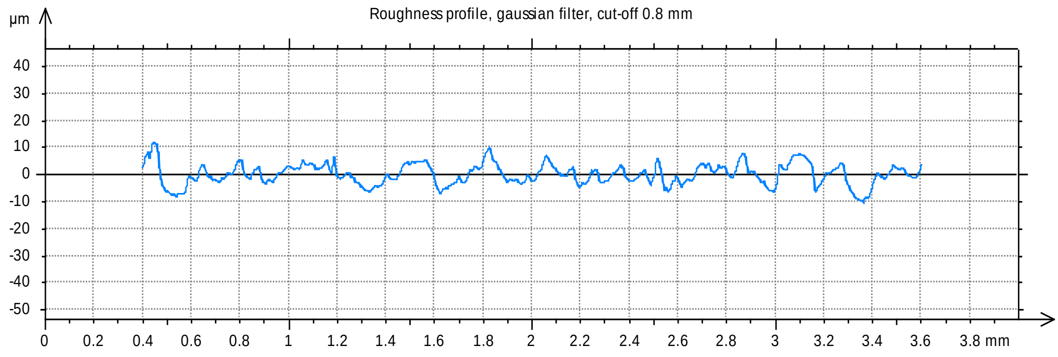

Figure 4.2 shows profile curve of surface roughness variation about mean

3 . Speed(36.31),feed(.15),doc(1.2)

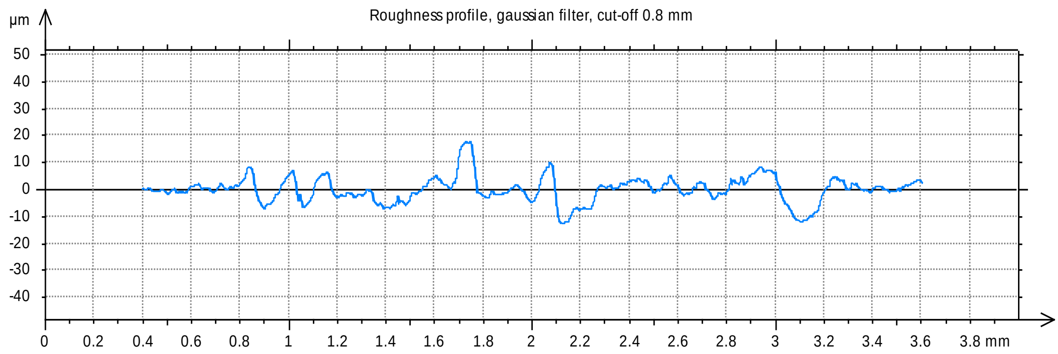

Fig. 4.3 Ra=3.27 µm profile curve of surface roughness

4.Speed(36.31m/min),feed(0.05mm/rev)doc(0.9mm)

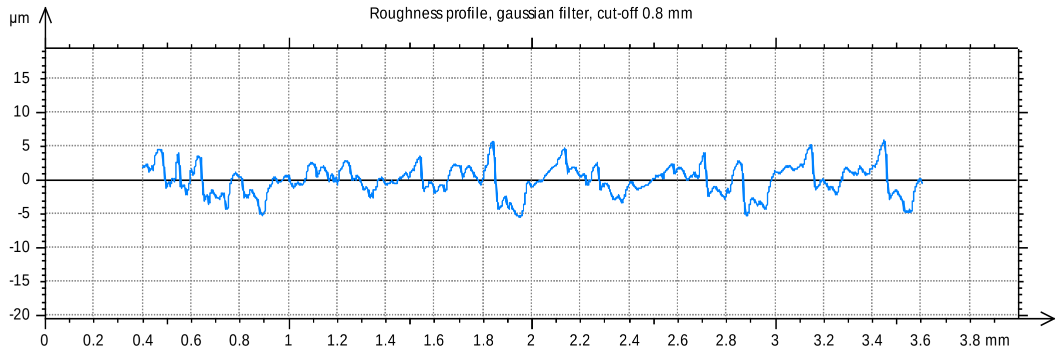

Fig. 4.4 profile curve of surface roughness, Ra=1.58 µm

5. Speed(36.31)feed(0.1),doc(0.9)

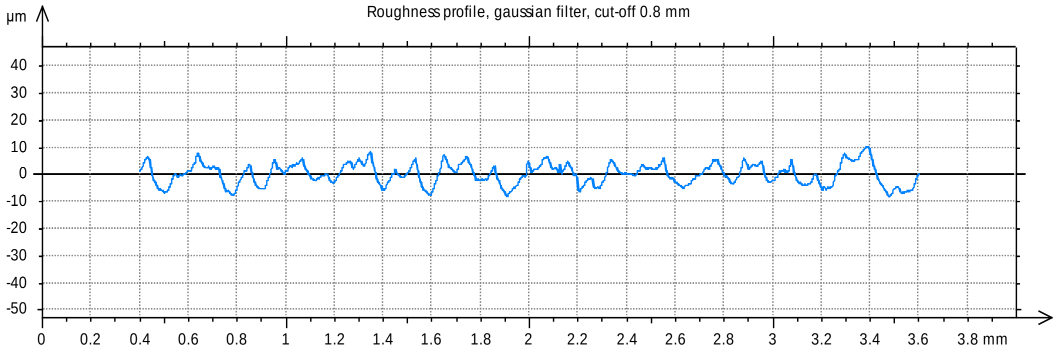

Fig. 4.5 profile curve of surface roughness Ra=2.97 µm

6 . Speed(36.31)feed(0.15)doc(0.9)

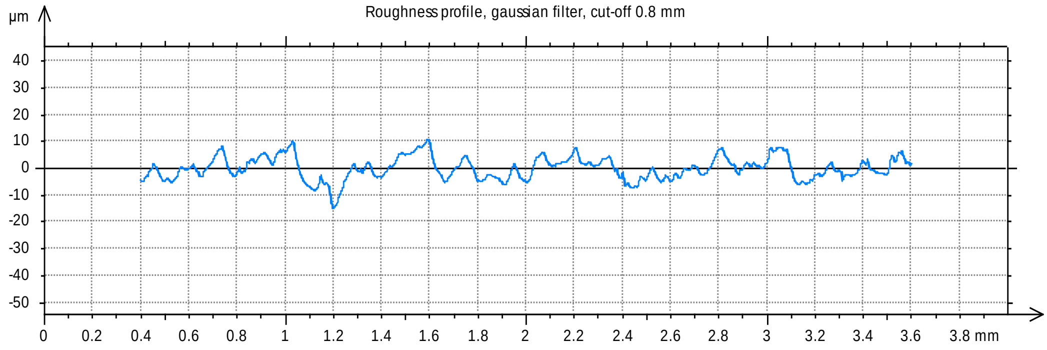

Fig. 4.6 profile curve of surface roughness Ra=1.48µm

7 . Speed(36.31),feed(0.05),doc(0.6)

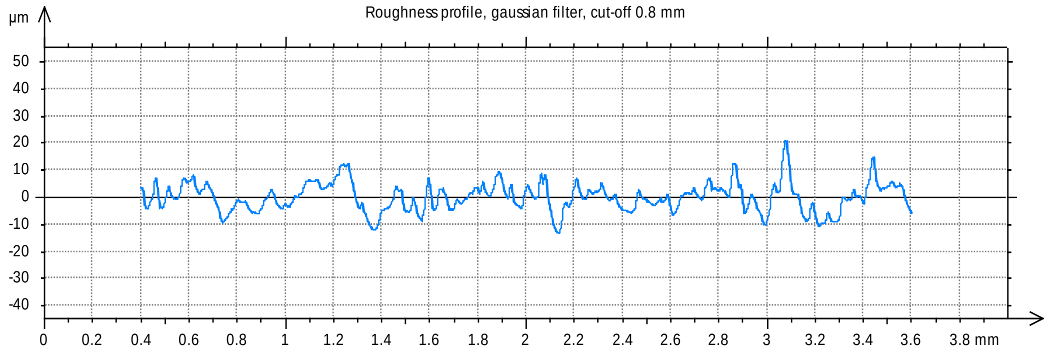

Fig.4.7 profile curve of surface roughness Ra=3.69µm

8. Speed(36.31),feed(0.1),doc(0.6)

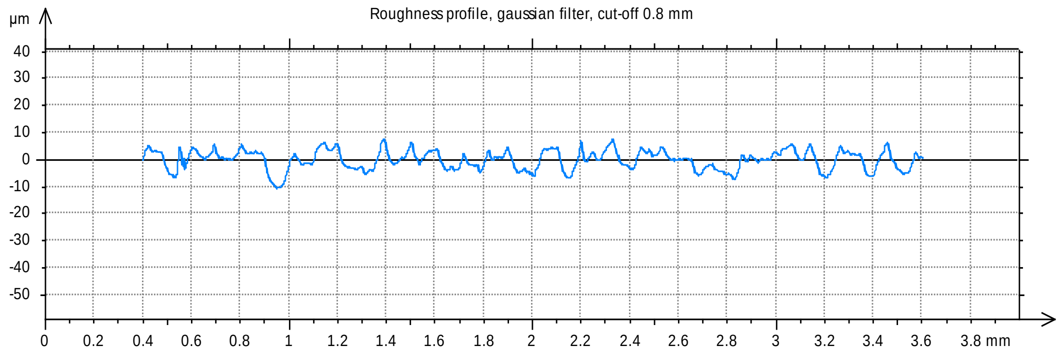

Fig. 4.8 profile curve of surface roughness Ra=2.91µm

9 .Speed(36.31),feed(0.15)doc(0.6)

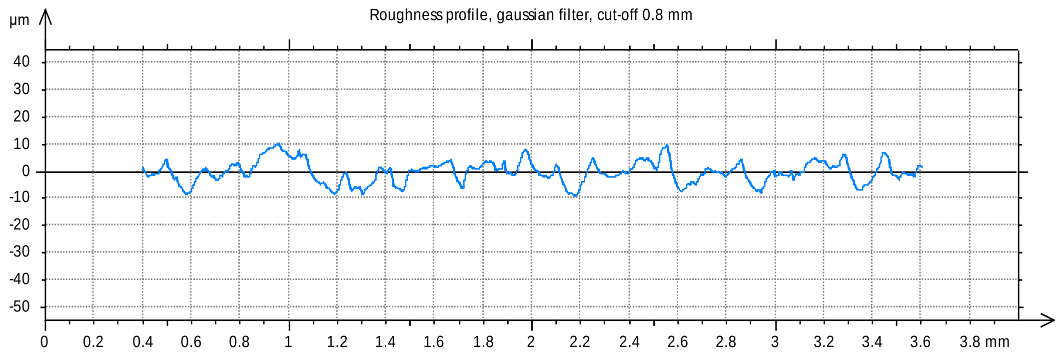

Fig. 4.9 profile curve of surface roughness Ra=3.3µm

Graphical analysis for variable surface roughness at constant speed (639rpm)

10. Speed(80.29m/min),feed(0.05),doc(1.2)

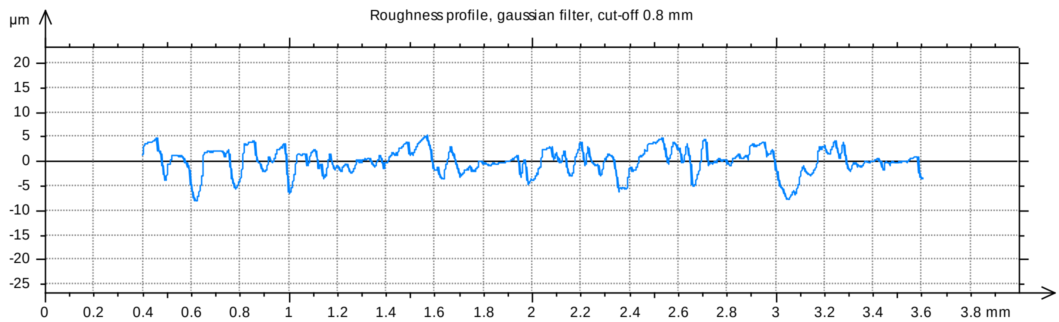

Fig. 4.10 profile curve surface roughness ,mean Ra=1.99µm

11 . Speed(80.29),feed(0.1),doc(1.2)

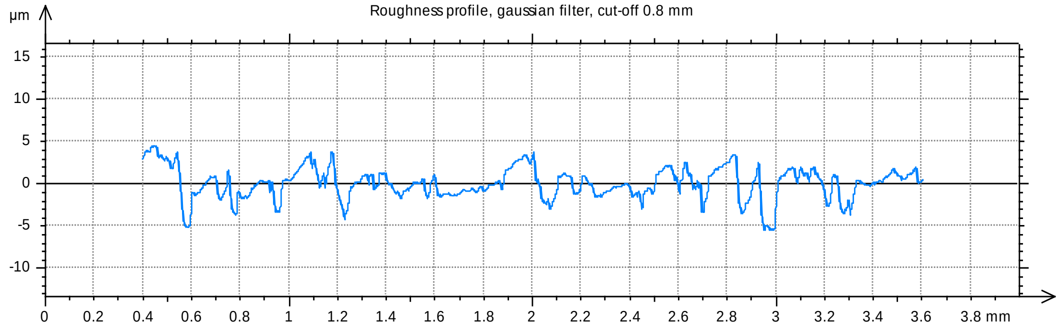

Fig. 4.11 profile curve of surface roughness Ra=1.37µm

12 .Speed(80.29),feed(0.15),doc(1.2)

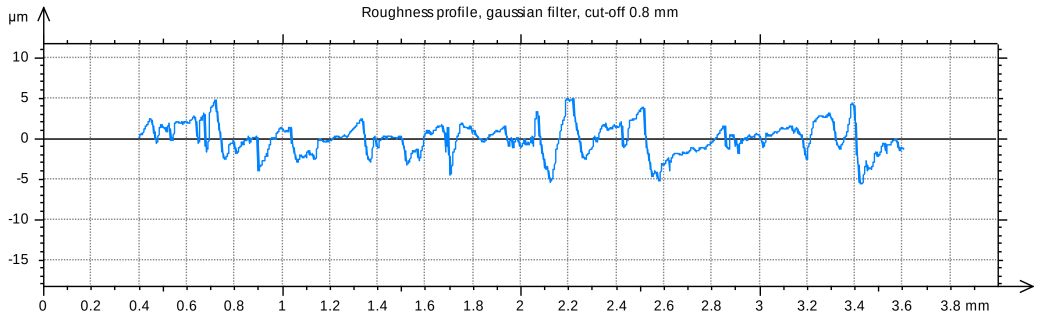

Fig. 4.12 profile curve surface roughness Ra=1.48µm

13 . Speed(80.29),feed(0.05),doc(0.6mm)

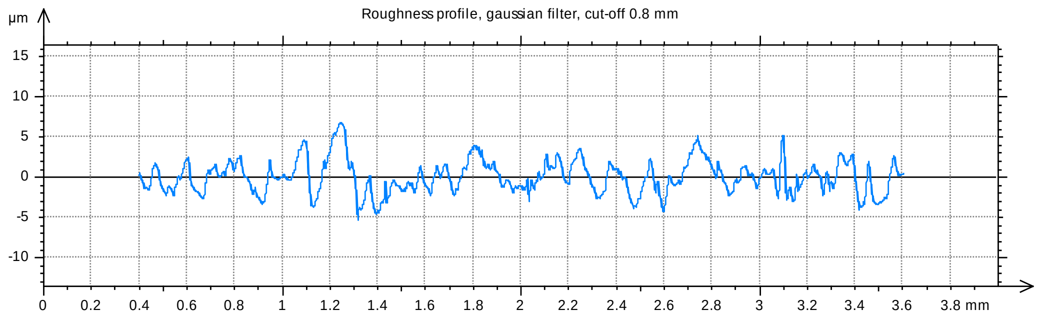

Fig. 4.13 profile curve of surface roughness Ra=1.68µm

14. Speed(80.29m/min),feed(0.1mm/sec),doc(0.6mm)

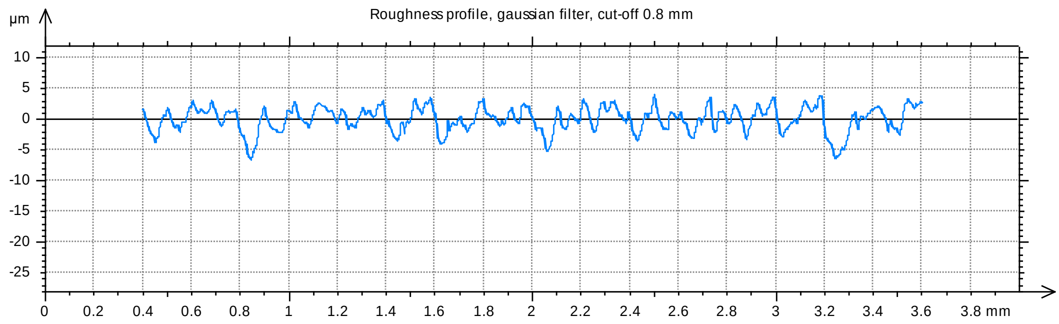

Fig. 4.14 profile curve of surface roughness Ra=1.49µm

15 . Speed(80.29m/min),feed(0.15mm/rev),doc(0.6mm)

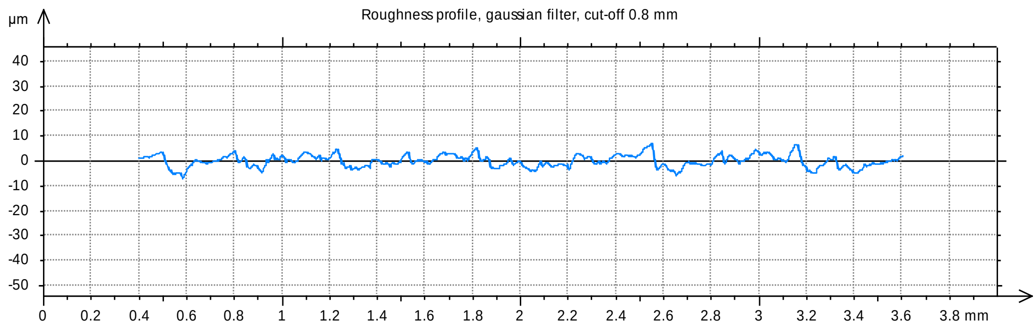

Fig. 4.15 profile curve of surface roughness ,Ra=1.9µm

16. Speed(80.29m/min),feed(0.05mm/rev),doc(0.9mm)

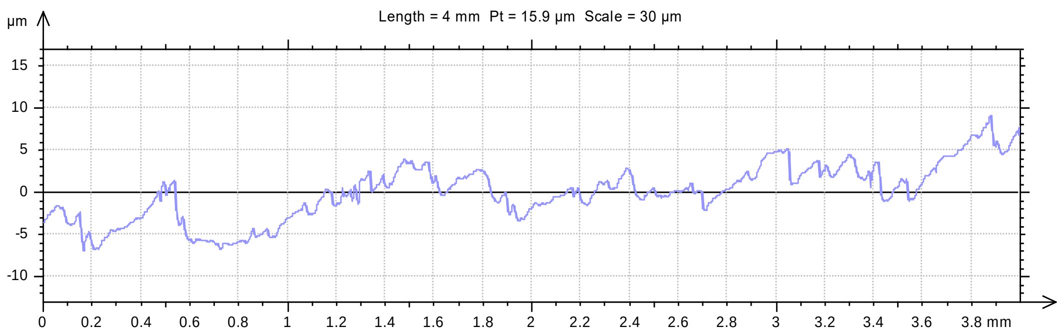

Fig. 4.16 profile curve surface roughness Ra=0.92µm

17. .Speed(80.29m/min),feed(0.1mm/rev),doc(0.9mm)

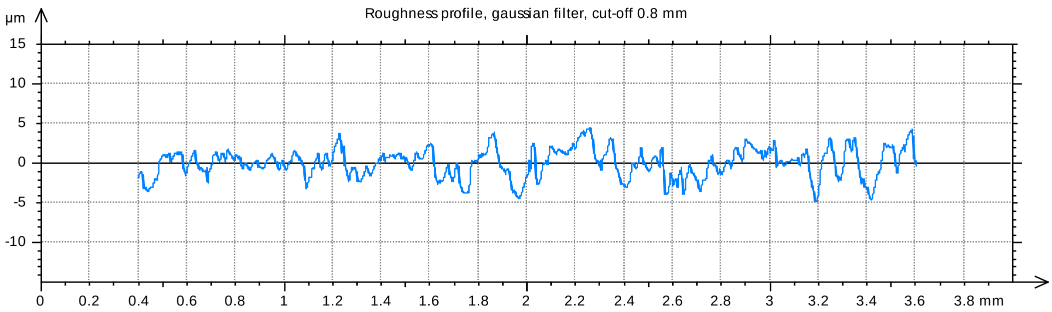

Fig.4.17, profile curve of surface roughness Ra=0.98µm

18. Speed(80.29m/min),feed(0.15mm/rev),doc(0.9mm)

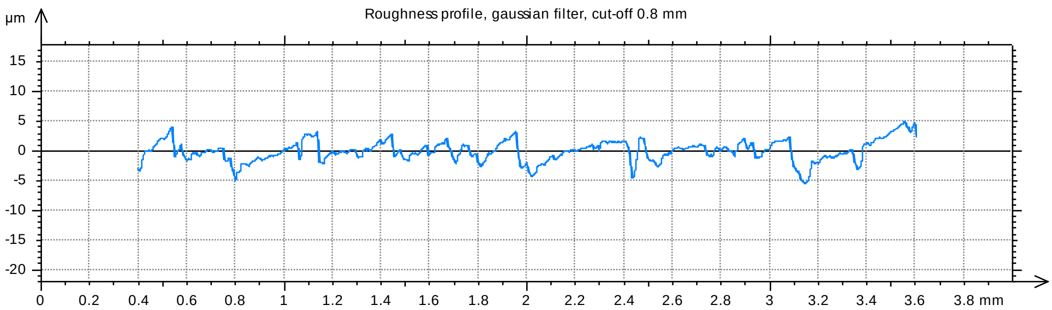

Fig.4.18 profile curve of surface roughness Ra=0.94µm

Graphical analysis for variable surface roughness at constant speed (1000rpm)

19 . Speed(125.66m/min),feed(0.1mm/rev),doc(1.2mm)

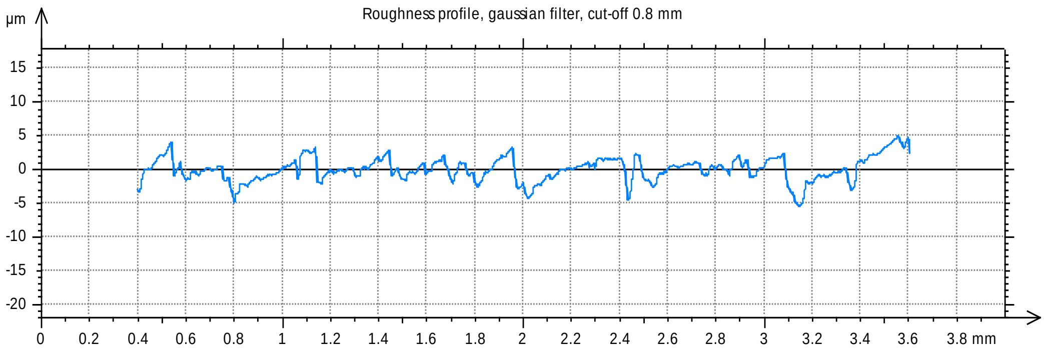

Fig. 4.19 profile curve of surface roughness Ra=1.18µm

20. Speed(125.66m/min),feed(0.15mm/rev),doc(1.2mm)

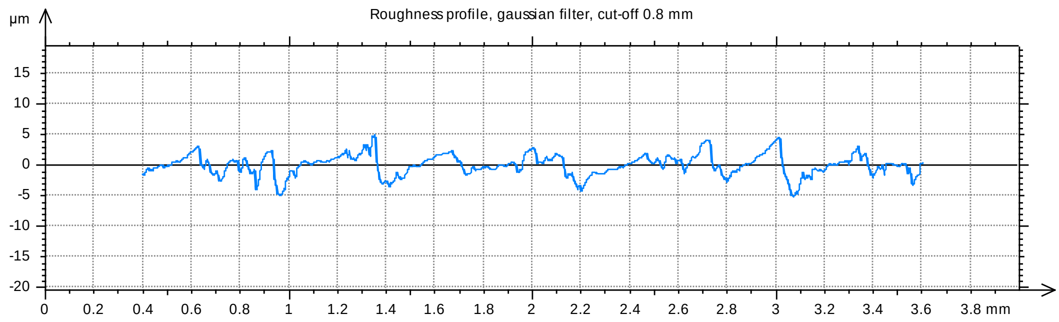

Fig. 4.20 profile curve of surface roughness Ra=1.3µm

21. Speed(125.66m/min),feed(0.05mm/rev),doc(0.6mm)

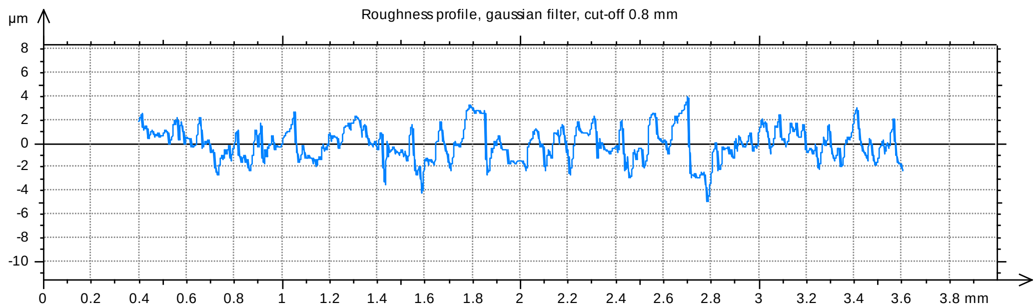

Fig. 4.21 profile curve of surface roughness Ra=1.19µm

22. Speed(125.66m/min),feed(0.1mm/rev),doc(0.6mm)

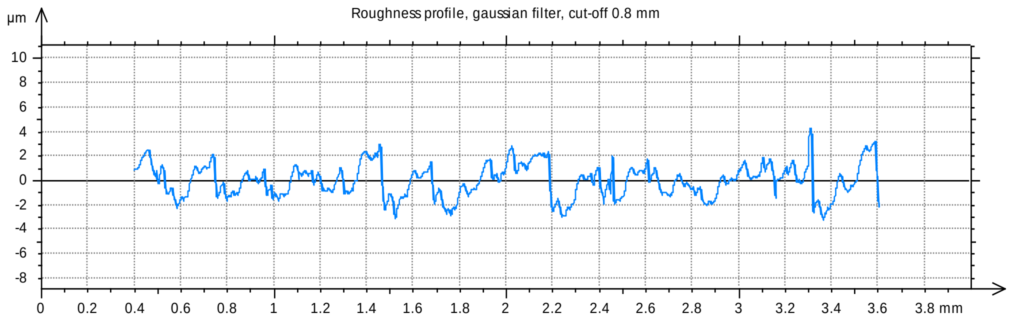

Fig. 4.22 profile curve of surface roughness Ra=1.19µm

23. Speed(125.66m/min),feed(0.15mm/rev),doc(0.6mm)

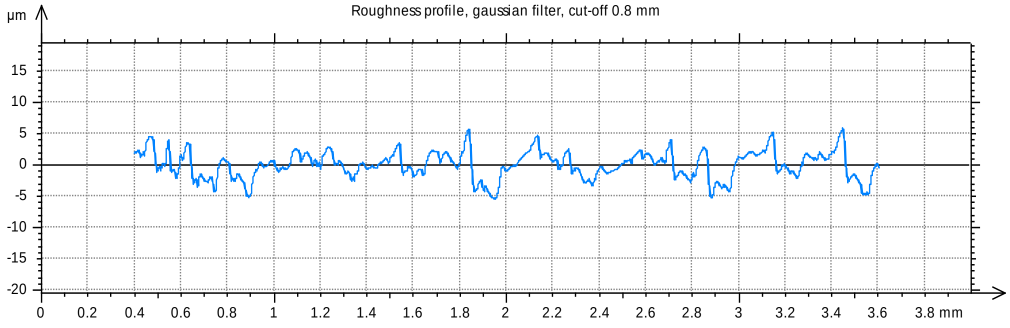

Fig. 4.23 profile curve of surface roughness Ra=1.58μm

24. Speed(125.66m/min),feed(0.05mm/rev),doc(0.9mm)

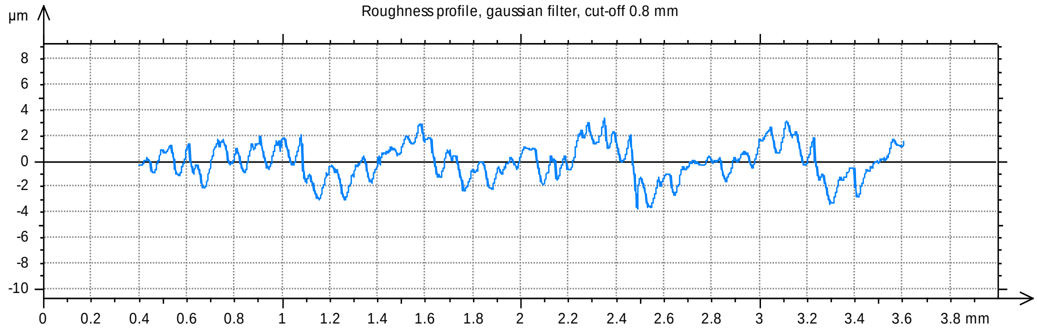

Fig. 4.24 profile curve of surface roughness Ra=1.07μm

25. Speed(125.66m/min),feed(0.1mm/rev),doc(0.9mm)

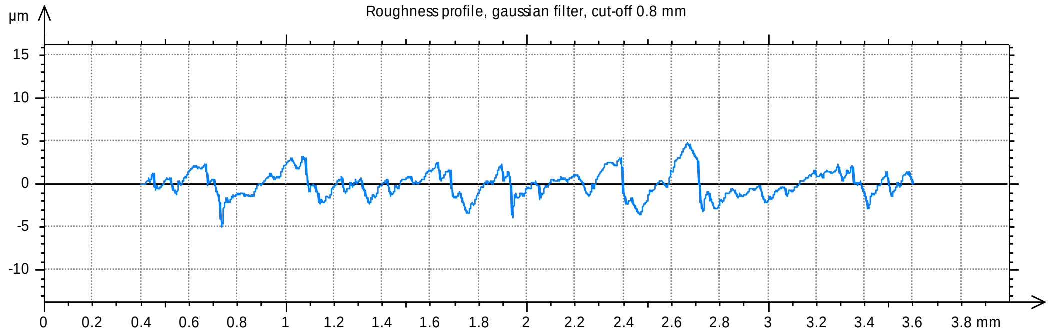

Fig. 4.25 profile curve of surface roughness Ra=1.25μm

26. Speed(125.66m/min),feed(0.15mm/rev),doc(0.9mm)

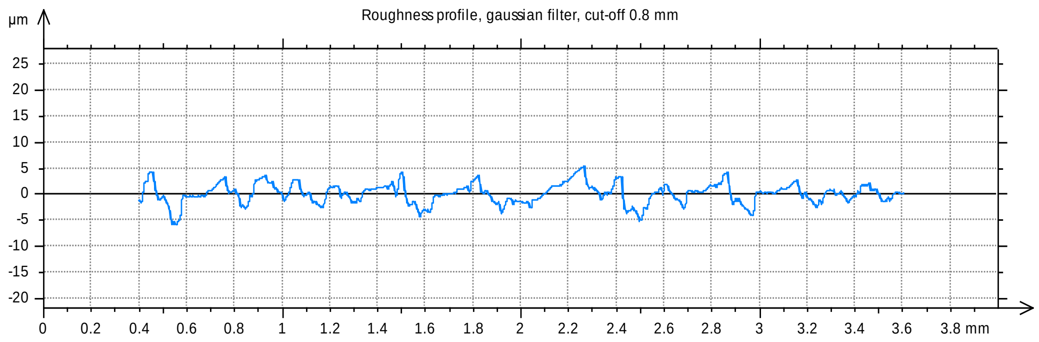

Fig. 4.26 profile curve of surface roughnessRa=1.58µm

27. Speed(125.66m/min) feed(0.1mm/rev),doc(1.2mm)

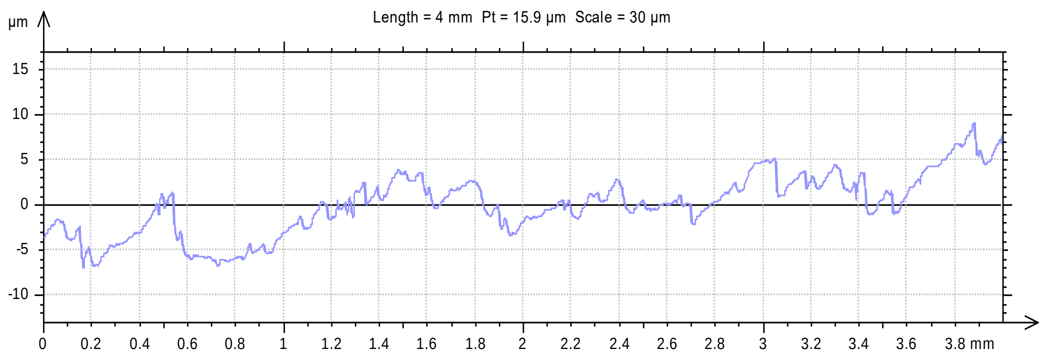

Fig.4.27.profile curve of surface roughness Ra=1.98µm

Average Roughness in micro-meters or micro-inches. Ra is the arithmetic mean deviation of the profile This section explains the main parameters of ISO 4287:1997. Each parameter is classified according to primary profile (P), roughness profile (R), and waviness profile (W) in order to evaluate different aspects of the profile. (When the wavelengths of the waviness and primary profile components are compared, the surface roughness component is the asperity component of that which has the comparatively shorter wavelength.).all the above profile curve explain the different values of different parameter ,all above graph as cut off 0.4mm.with different values of Ra. Ra is by far the most commonly used Surface Finish parameter. One reason it is so common is that it is fairly easy to take the absolute value of a signal and integrate the signal using analog electronics, so Ra could be measured by instruments that contain no digital circuits. Ra, while common, is not sufficient to completely characterize the roughness of a surface. Depending on the application, surfaces with the same Ra can perform quite differently. Here are 4 surfaces with the same Ra and quite different shapes **.** The stylus must be polished, because it will wear down over time. The mode of wear varies, making the stylus flat or rounded depending on the material and shape of the measurement target object. Different stylus shapes will naturally generate different wave profiles. One method for determining stylus wear is to use a commercially available wear inspection test piece. Wear is determined by comparing the data profile (groove width) of the test piece before and after the wear of the stylus. The atomic force microscope measures the asperity of a sample using the atomic forces between the tip and the sample. To perform measurement, the user moves the cantilever, equipped with a sharp tip (probe) at its end, into proximity of a sample surface to a distance of several nanometers. In order to maintain a constant force between the tip and the sample (a constant deflection of the cantilever), the atomic force microscope gives feedback to the piezo scanner while scanning. The displacement provided as feedback to the piezo scanner is measured to obtain the z-axial displacement, which is the surface structure.

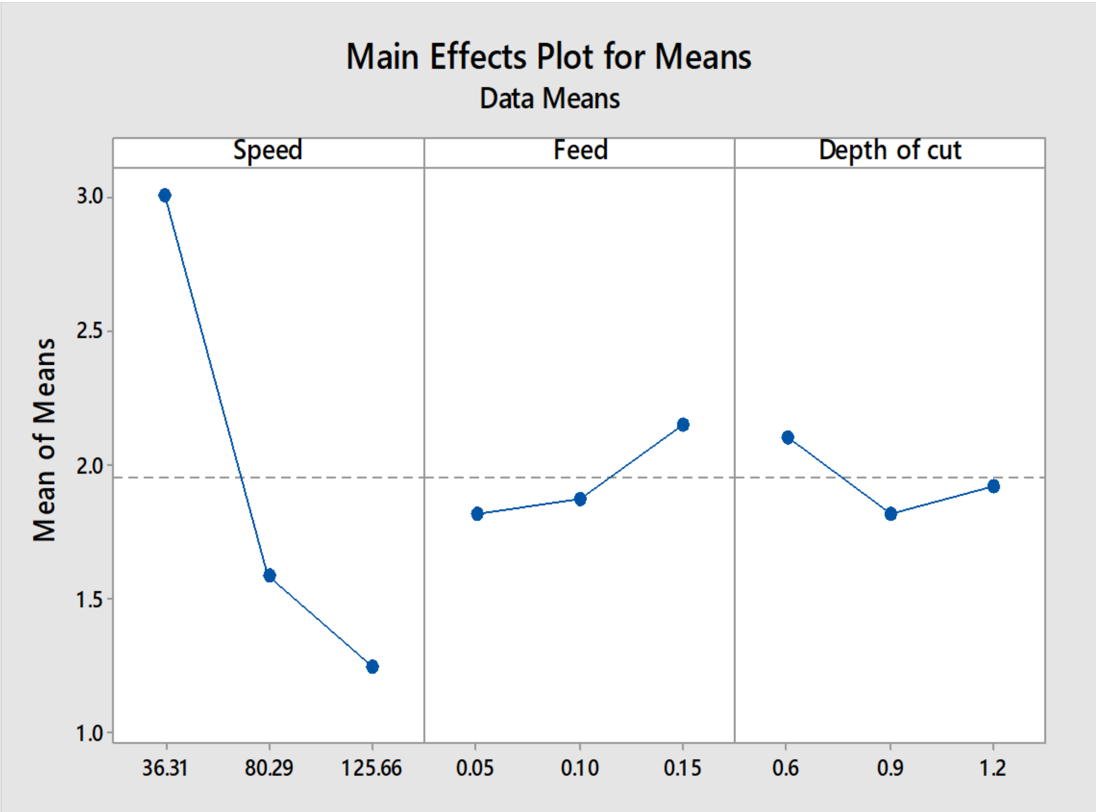

Fig. 4.26(variation of speed ,feed,depth of cut,with mean of means)

Above graph show that speed increases mean of means surface decreases ,feed increases the mean of means surface increases, as depth of cut increases mean of means surfaces first decreases then increase up to mean 2.0

Response Table for Signal to Noise Ratios

Use the response tables to select the best level for each factor. Usually you have the following objectives with a Taguchi design:

- Minimize the standard deviation
- Maximize the S/N ratio
- Meet a target with the mean (static design)
- Meet a target with the slope (dynamic design)

Use the delta and rank values to identify the factors that have the largest effect on each response characteristic. Then, determine which levels of these factors meet your objectives. Sometimes, the best level of a factor for one response characteristic is different from the best level for a different response characteristic. To resolve this issue, it may help to predict the results for several combinations of factors levels to see which one produces the best result.

Table 4.2 (speed, feed, depth of cut of different level)

Level	Speed	Feed	Depth of cut
1	-9.349	-4.341	-5.725
2	-3.968	-4.808	-4.543
3	-1.832	-6.000	-4.880
Delta(max-min)	7.517	1.659	1.182
Rank	1	2	3

Above matrix table shows the different level speed ,feed,depth of cut,the contribution of there role during machining operation

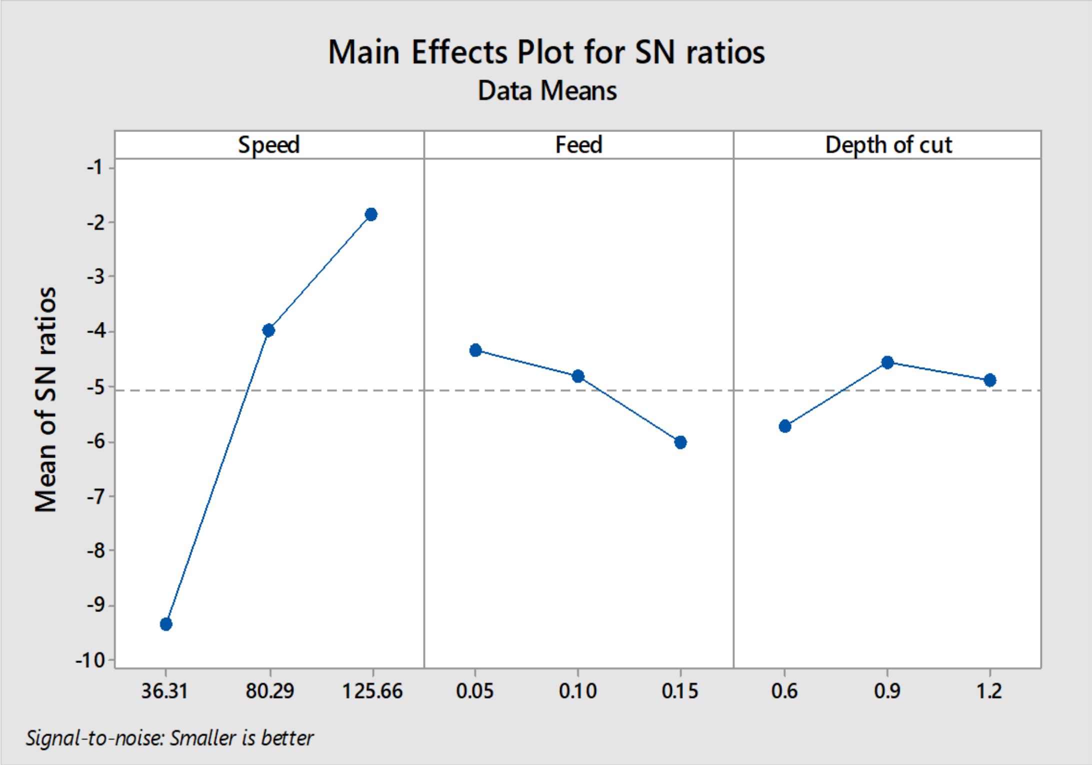

Fig. 4.27(speed feed depth of cut at different mean of S-N ratios)

Above graph show that smaller is better (signal to noise),at speed of 125.66m/min value of mean is (-1.5),feed at 0.05mm/rev better mean occurs ,depth of cut is 0.6 get better result of mean of S-N ratio.

ANOVA

Table 4.3 Analysis of variance with different speed feed depth of cut

Analysis of Variance						
Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution%
Speed	2	15.5547	7.7774	56.01	0.000	80.69
Feed	2	0.5735	0.2868	2.07	0.153	2.975
Depth of cut	2	0.3696	0.1848	1.33	0.287	1.917
Error	20	2.7774	0.1389			14.40
Total	26	19.2752				

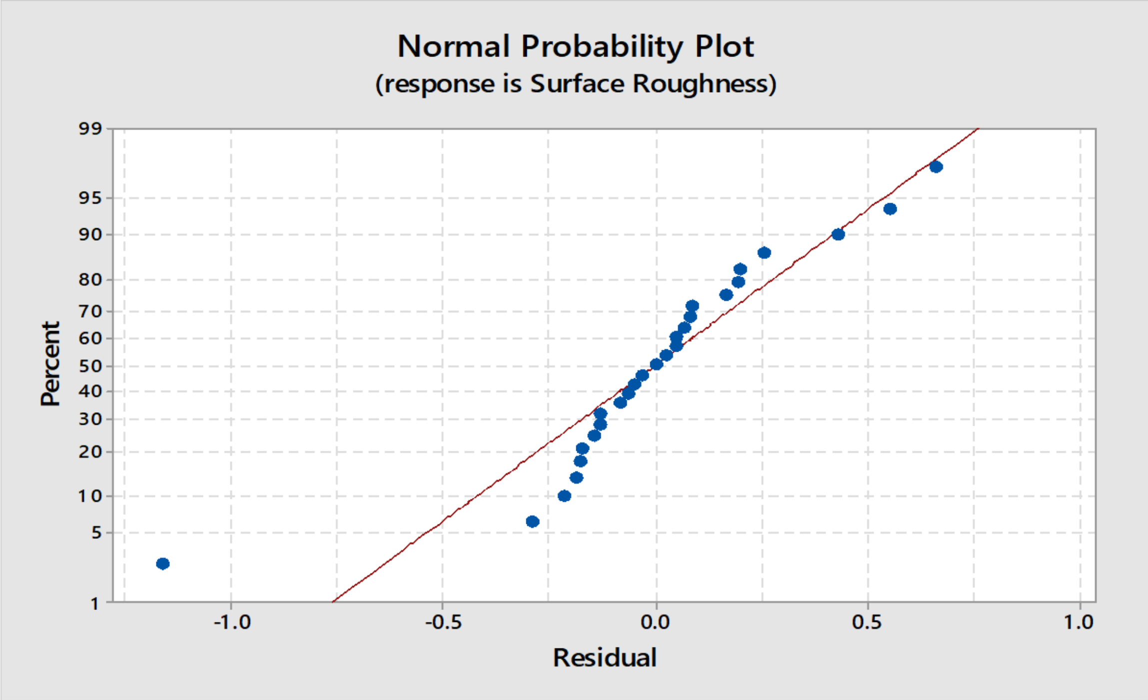

Fig. 4.28(normal probability plot response is surface roughness)

Above figure show that response is surface roughness normal probability plot within the residual and percent ,the blue dotted shows the percentage probability of resudal at different stage ,minimum at (-.25) residual and maximum at 98 percent,maximum probability at 40 to 80 percent

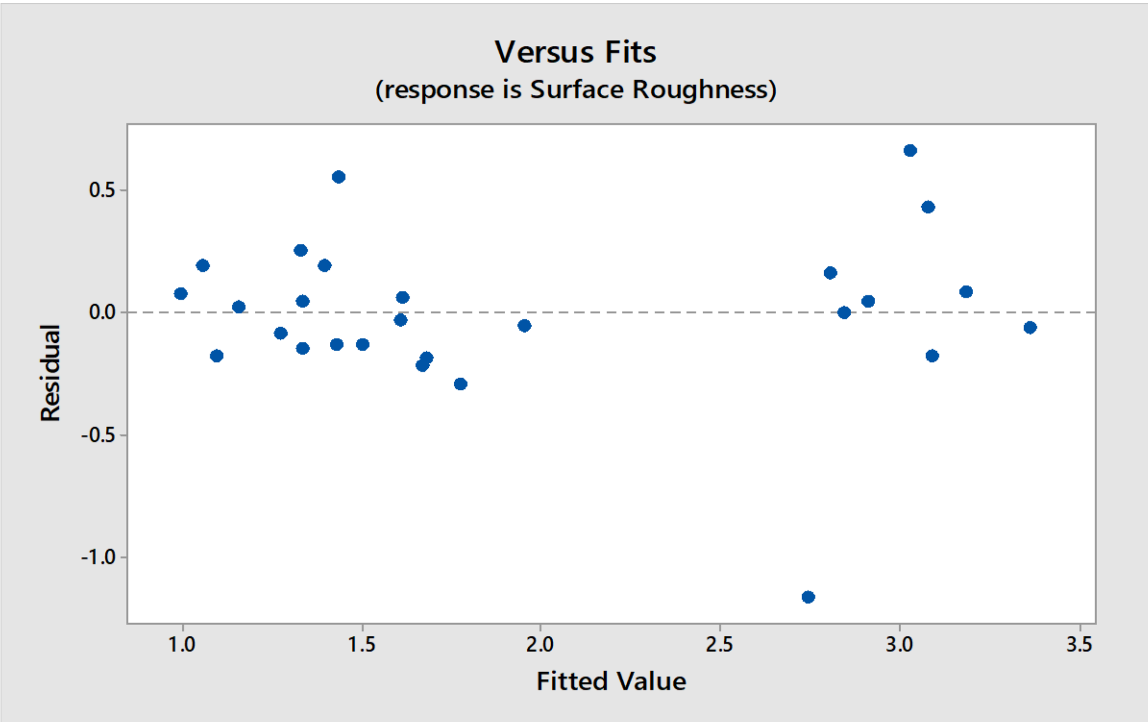

Fig. 4.29 (Response is surface roughness versus fits versus residual)

Above figure shows that residual values find out in discret pattern but main values of residual are found at mean value of 0.0 residual of different fitted values. The size of the studentized residual should be independent of its predicted value. In other words, the vertical spread of the studentized residuals should be approximately the same for each bowler. In this case the plot looks OK. Don't be alarmed that Mark's games stand out as a whole. The spread from bottom-to-top is not out of line with his competitors, despite their protestations about the highest score .

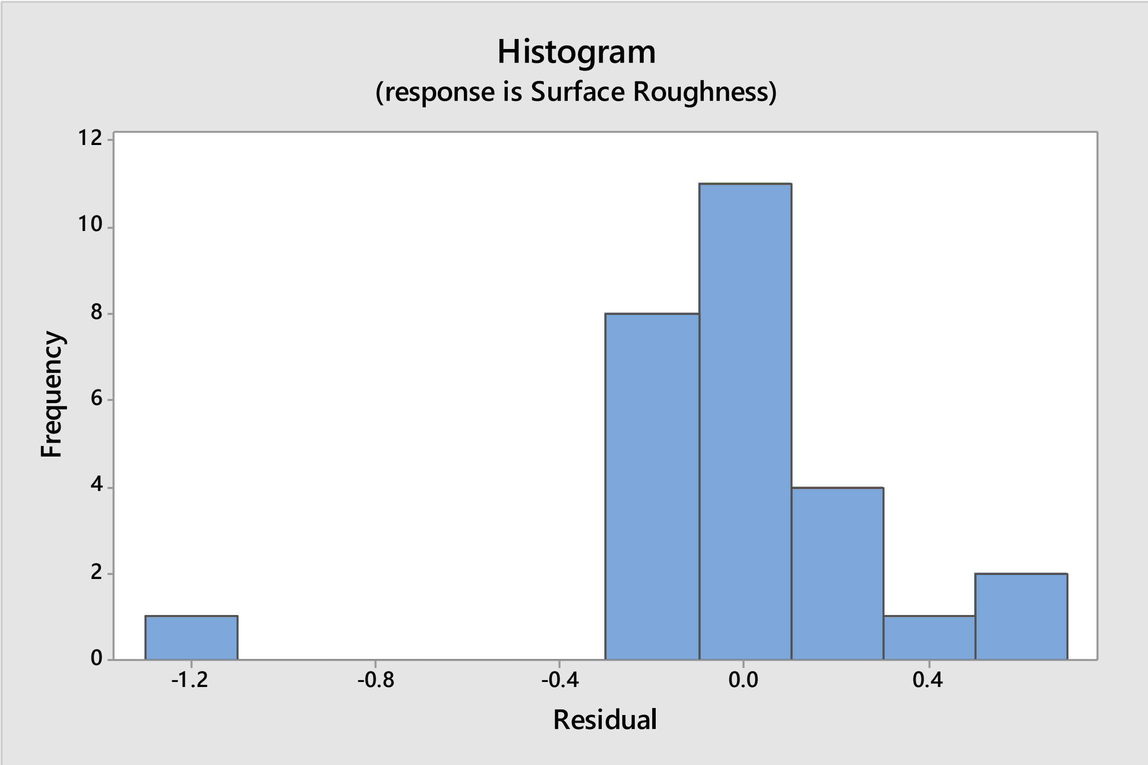

Fig. 4.30(histogram of response is surface roughness and frequency relation maximum frequency at 0.0 residual)

Above histogram graph shows that (response in surface roughness) ,frequency versus residual

Different values of frequency at different residual maximum frequency at f(0.0) residual and minimum frequency at (-0.8)and(0.4)

A histogram is a graph that you can use to assess the shape and spread of continuous sample data. You might create a histogram before or during an analysis to help confirm assumptions and guide additional analyses.To draw a histogram, Minitab divides sample values into intervals called bins. By default, each bar on the histogram represents the number of observations falling within a bin (the frequency).

Minitab automatically determines an optimal number of bins, but you can edit the number of bins in addition to the intervals covered by each.

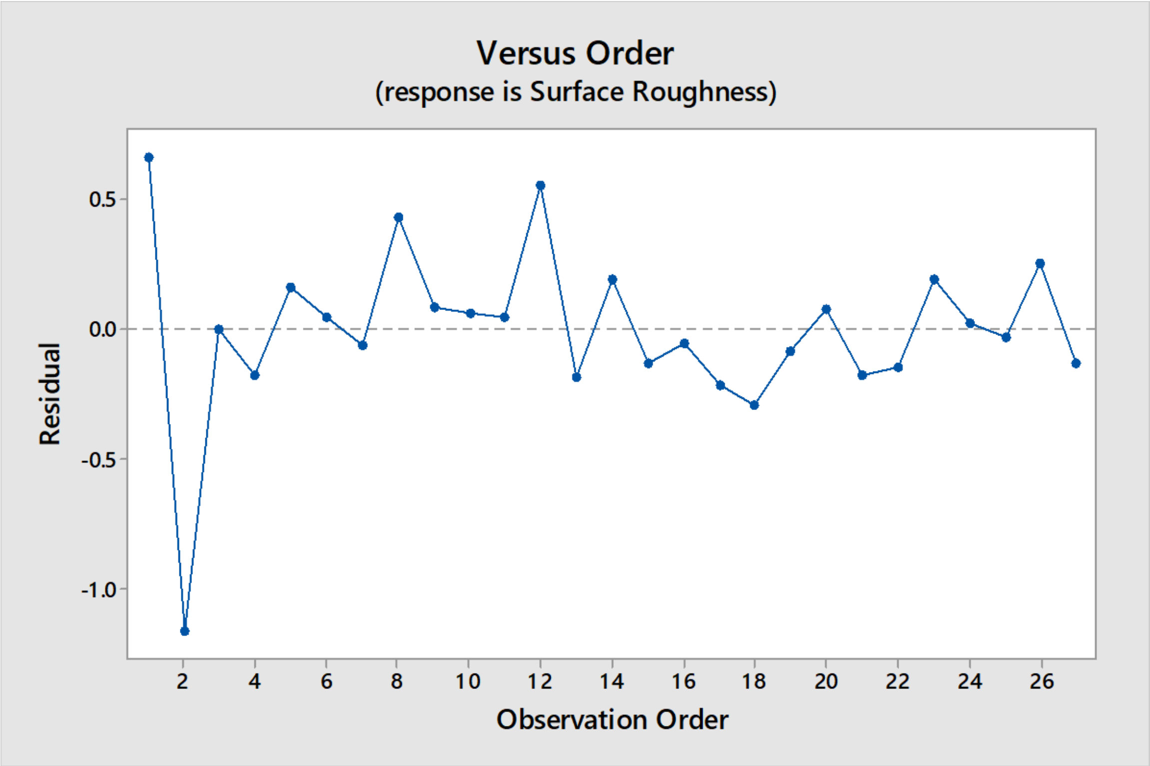

Fig. 4.31(versus order response is surface roughness against residual related observation order)

Above figure shows that residual versus observation order of (response is surface roughness) versus order at different observation order found different value of residual in above graph maximum residual at 1,and minimum residual at 2

Regression Analysis: Log Ra versus Log S, Log F, Log D

Table 4.4 Analysis of Variances

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	**3**	**0.707932**	**0.235977**	**41.02**	**0.000**
Log S	**1**	**0.670250**	**0.670250**	**116.52**	**0.000**
Log F	**1**	**0.028020**	**0.028020**	**4.87**	**0.038**
Log D	**1**	**0.009662**	**0.009662**	**1.68**	**0.208**
Error	23	0.132299	0.005752		
Total	26	0.840231			

Regression Equation

Log Ra = 1.724 - 0.7067 Log S + 0.1635 Log F - 0.153 Log D

Ra = 52.96 $S^{(-0.7067)}$ $F^{(0.1635)}$ $D^{(-0.153)}$

Table 4.5 Fits and Diagnostics for Unusual Observations

Obs	Log Ra	Fit	Resid	Std Resid	
2	0.1987	0.4156	-0.2170	-3.13	R
12	0.2989	0.1529	0.1459	2.09	R

R Large residual

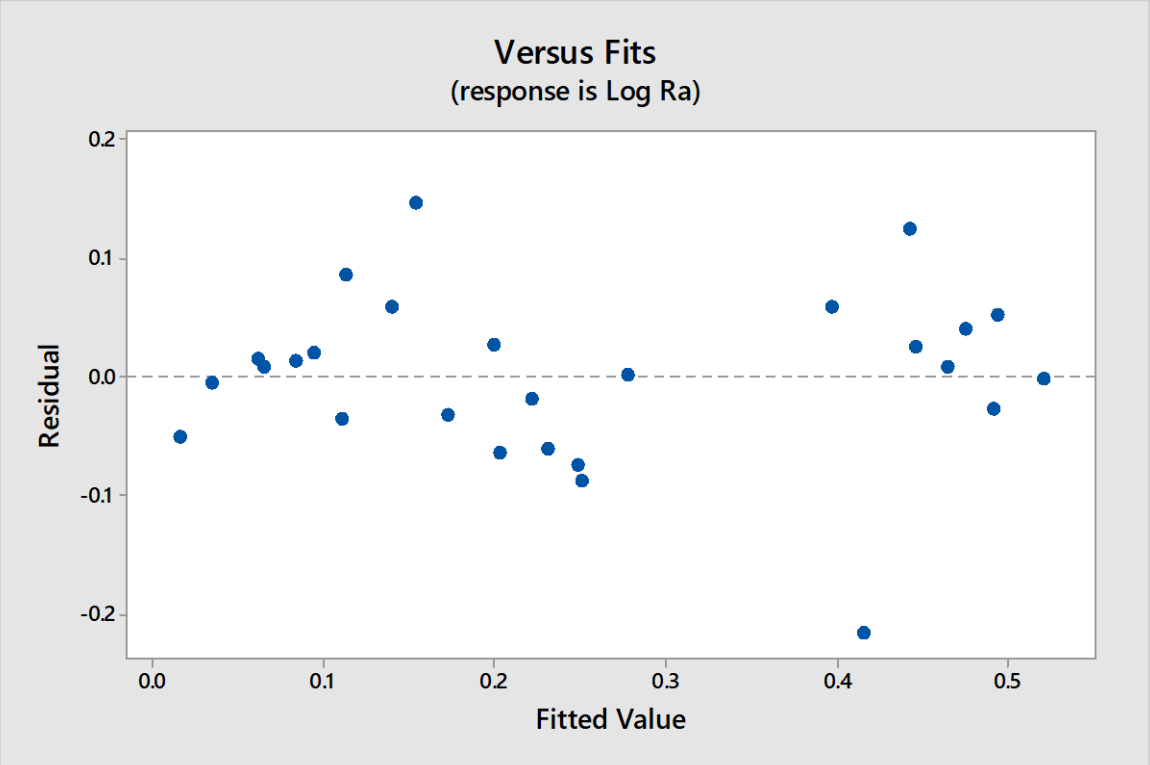

Fig. 4.32(response is log Ra against residual and fitted value)

Above figure shows that residual versus fitted value (response is LogRa) in discreet manner residual shows different values at different fitted value , major point shows the lies between 0.1 to 0.3.the maximum residual lies between 0.1 -0.2 that value is 0.18,and minimum value lies between 0.4 -0.5 that minimum value is -0.1 .

4.2 FORCE ANALYSIS

Table 4.6(cutting force,feed force,thrust force and resultant forces)

S. No.	RPM	Speed (m/min)	FEED (mm/rev)	DOC (mm)	Fc (N)	F_f (N)	F_t (N)	F_R(N)
1	289	36.39	0.05	1.2	78.4	39.2	9.8	88.2
2	289	36.39	0.1	1.2	225.4	117.6	19.6	255
3	289	36.39	0.15	1.2	352.8	166.6	9.8	390.3
4	639	80.29	0.05	1.2	186.2	147	19.6	238
5	639	80.29	0.1	1.2	215.6	147	19.6	261.7
6	639	80.29	0.15	1.2	294	196	19.6	353.9
7	1000	125.66	0.05	1.2	127.4	78.4	9.8	149.9
8	1000	125.66	0.1	1.2	186.2	107.8	9.8	215.4
9	1000	125.66	0.15	1.2	215.6	107.8	9.8	241.2
10	289	36.39	0.05	0.6	68.6	49	9.8	84.87
11	289	36.39	0.1	0.6	117.6	58.8	9.8	131.8
12	289	36.39	0.15	0.6	166.6	78.4	19.6	185.2
13	639	80.29	0.05	0.6	78.4	68.6	9.8	104.6
14	639	80.29	0.1	0.6	147	107.8	9.8	182.6
15	639	80.29	0.15	0.6	225.4	147	19.6	269.8
16	1000	125.66	0.05	0.6	88.2	78.4	9.8	118.4
17	1000	125.66	0.1	0.6	147	107.8	9.8	182.6
18	1000	125.66	0.15	0.6	156.8	49	19.6	165.4
19	289	36.39	0.05	0.9	68.6	39.2	9.8	79.62
20	289	36.39	0.1	0.9	137.2	58.8	9.8	149.6
21	289	36.39	0.15	0.9	186.2	68.6	9.8	198.7
22	639	80.29	0.05	0.9	98	78.4	9.8	125.9
23	639	80.29	0.1	0.9	205.8	147	29.4	254.6
24	639	80.29	0.15	0.9	294	196	29.4	354.6
25	1000	125.66	0.05	0.9	156.8	117.6	19.6	197
26	1000	125.66	0.1	0.9	225.4	147	9.8	269.3
27	1000	125.66	0.15	0.9	196	98	9.8	219.4

4.3 Taguchi Analysis: Resultant F versus Speed, Feed, Depth of cut

Table 4.7 (SNRA AND MEAN)

S.No.	Speed(m/min)	Feed	Depth of cut	Resultant F	SNRA	MEAN
1	36.39	0.05	0.6	84.870	38.5751	84.870
2	36.39	0.05	0.9	79.616	38.0200	79.616
3	36.39	0.05	1.2	88.200	38.9094	88.200
4	36.39	0.10	0.6	131.846	42.4013	131.846
5	36.39	0.10	0.9	149.591	43.4981	149.591
6	36.39	0.10	1.2	254.988	48.1304	254.988
7	36.39	0.15	0.6	185.166	45.3512	185.166
8	36.39	0.15	0.9	198.677	45.9629	198.677
9	36.39	0.15	1.2	390.281	51.8276	390.281
10	80.29	0.05	0.6	104.635	40.3936	104.635
11	80.29	0.05	0.9	125.883	41.9994	125.883
12	80.29	0.05	1.2	238.041	47.5330	238.041
13	80.29	0.10	0.6	182.554	45.2278	182.554
14	80.29	0.10	0.9	254.611	48.1176	254.611
15	80.29	0.10	1.2	261.680	48.3554	261.680
16	80.29	0.15	0.6	269.812	48.6212	269.812
17	80.29	0.15	0.9	354.565	50.9939	354.565
18	80.29	0.15	1.2	353.887	50.9773	353.887
19	125.66	0.05	0.6	118.414	41.4681	118.414
20	125.66	0.05	0.9	196.978	45.8883	196.978
21	125.66	0.05	1.2	149.911	43.5167	149.911
22	125.66	0.10	0.6	182.554	45.2278	182.554

23	125.66	0.10	0.9	269.277	48.6040	269.277
24	125.66	0.10	1.2	215.377	46.6640	215.377
25	125.66	0.15	0.6	168.675	44.5410	168.675
26	125.66	0.15	0.9	219.354	46.8229	219.354
27	125.66	0.15	1.2	241.247	47.6492	241.247

Table 4.8 Response Table for Signal to Noise Ratios Larger is better

Level	Speed	Feed	Depth of cut
1	43.63	41.81	43.53
2	46.91	46.25	45.55
3	45.60	48.08	47.06
Delta	3.28	6.27	3.53
Rank	3	1	2

Table 4.9 Response Table for Means

Level	Speed	Feed	Depth of cut
1	173.7	131.8	158.7
2	238.4	211.4	205.4
3	195.8	264.6	243.7
Delta	64.7	132.8	85.0
Rank	3	1	2

Use the response tables to select the best level for each factor. Usually you have the following objectives with a Taguchi design:

- Minimize the standard deviation
- Maximize the S/N ratio
- Meet a target with the mean (static design)
- Meet a target with the slope (dynamic design)

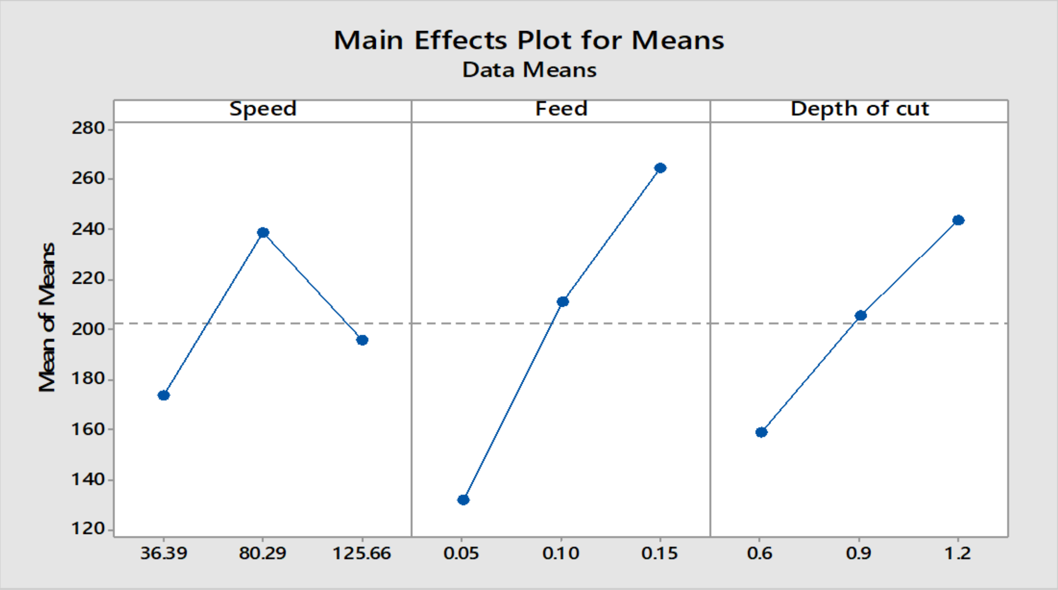

Fig. 4.33(Main effect plot for means of speed, feed and depth of cut at different speed)

Above figure shows that different speed ,feed ,depth of cut different level of resultant forces as speed increases force increases up to 246.66 N then decreases up to 196.67 N,

- As in figure feed increases resultant forces increases, maximum force 267.66 N at feed of 0.15mm
- As in figure depth of cut increases mean forces increases, the maximum force of 256,87 N at depth of cut 1.2 mm

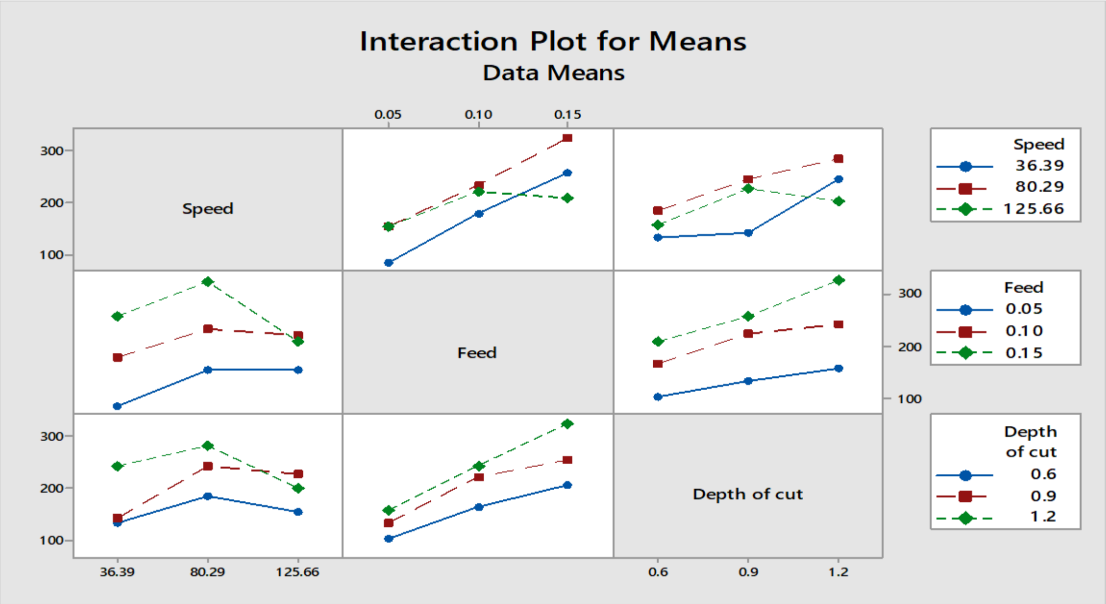

Fig. 4.34 (variation of speed.feed depth of cut at matrix form)

Above figure shows that speed ,feed,and depth of cut intraction between all three ,it’s a form of matrix of 3*3 that shows relation ao all three with varying one by one.

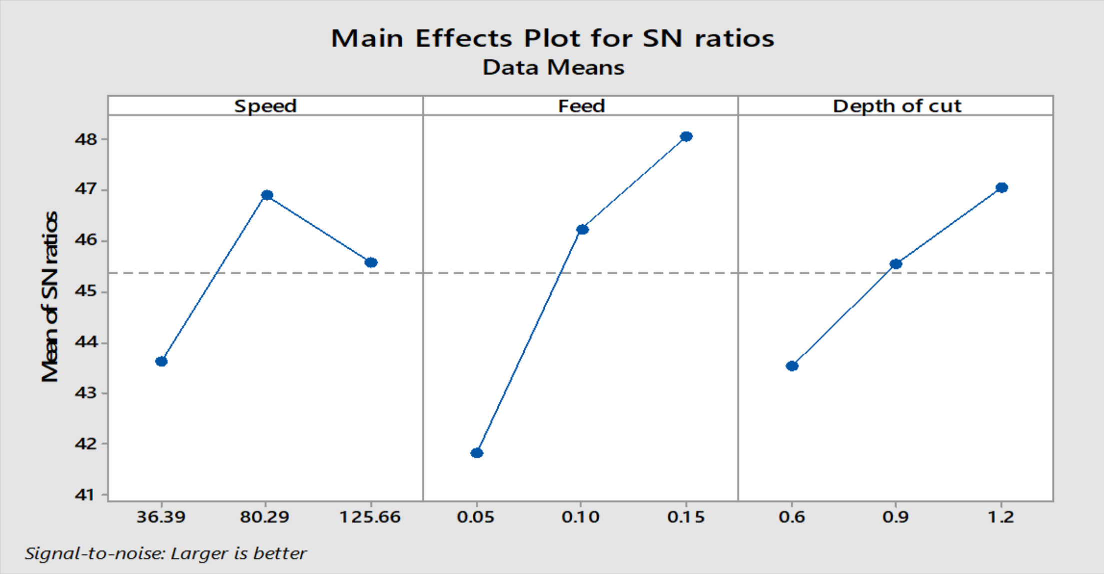

Fig. 4.35(Main effect of S-N ratio at larger is better)

Main effect plot for SN ratio- above graph shows that mean of SN ratio versus all three para meter like speed,feed, depth of cut, as speed increases SN ratio first increases up to speed 80.29m/min then decreases at 125.66m/min.

- As feed increases mean of SN ratios increase maximum value at 0.15mm/rev feed
- Depth of cut increases SN mean ratios increases maximum value at 1.2mm depth of cut.

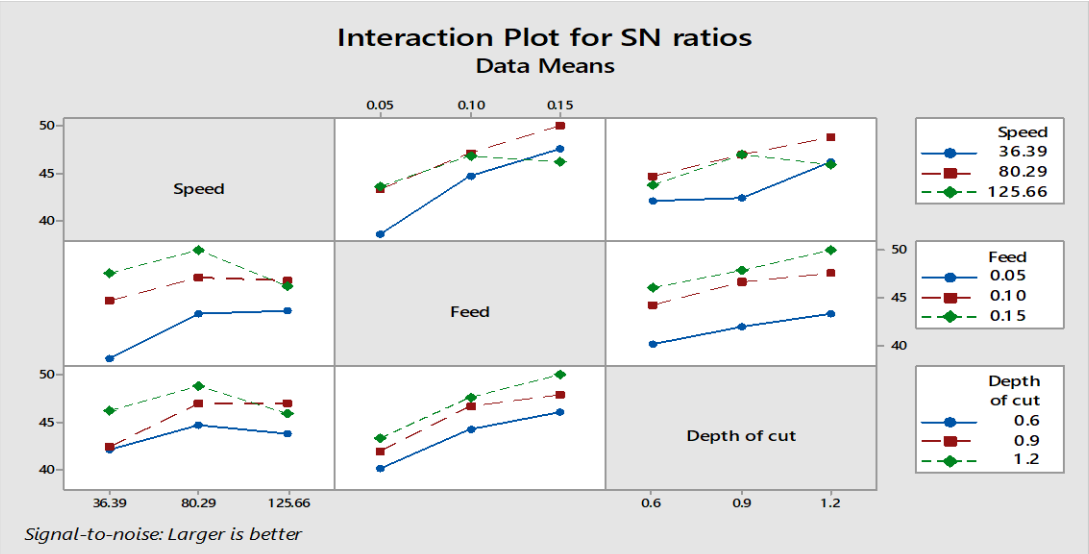

Fig. 4.36 (speed,feed depth of cut variation of different mode)

Above figure shows that the interaction for SN ratios between speed, feed ,and depth of cut signal to noise larger is better so larger value of speed(125.66m/min) and feed(0.15mm/rev) and depth of cut (1.2) are the optimal values.

ANOVA

Table 4.1 Analysis of Variance for Resultant F

Source	DF	SS	MS	F	P
Speed	2	19482	9741	4.11	0.032
Feed	2	80388	40194	16.98	0.000
Depth of cut	2	32624	16312	6.89	0.005
Error	20	47349	2367		
Total	26	179843			

Table 4.11 (Resultant forces and res1 and fits1)

S.No	Speed	Feed	Depth of cut	Resultant F	RESI1	FITS1
1	36.39	0.05	0.6	84.870	25.850	59.020
2	36.39	0.05	0.9	79.616	-26.074	105.690
3	36.39	0.05	1.2	88.200	-55.830	144.030
4	36.39	0.10	0.6	131.846	-6.722	138.568
5	36.39	0.10	0.9	149.591	-35.647	185.237
6	36.39	0.10	1.2	254.988	31.411	223.578
7	36.39	0.15	0.6	185.166	-6.645	191.811
8	36.39	0.15	0.9	198.677	-39.803	238.480
9	36.39	0.15	1.2	390.281	113.461	276.821
10	80.29	0.05	0.6	104.635	-19.100	123.735
11	80.29	0.05	0.9	125.883	-44.521	170.405
12	80.29	0.05	1.2	238.041	29.296	208.745
13	80.29	0.10	0.6	182.554	-20.729	203.283
14	80.29	0.10	0.9	254.611	4.659	249.952
15	80.29	0.10	1.2	261.680	-26.612	288.293
16	80.29	0.15	0.6	269.812	13.286	256.526

17	80.29	0.15	0.9	354.565	51.370	303.195
18	80.29	0.15	1.2	353.887	12.352	341.536
19	125.66	0.05	0.6	118.414	37.332	81.082
20	125.66	0.05	0.9	196.978	69.226	127.751
21	125.66	0.05	1.2	149.911	-16.180	166.091
22	125.66	0.10	0.6	182.554	21.924	160.629
23	125.66	0.10	0.9	269.277	61.978	207.299
24	125.66	0.10	1.2	215.377	-30.262	245.639
25	125.66	0.15	0.6	168.675	-45.197	213.872
26	125.66	0.15	0.9	219.354	-41.188	260.542
27	125.66	0.15	1.2	241.247	-57.635	298.882

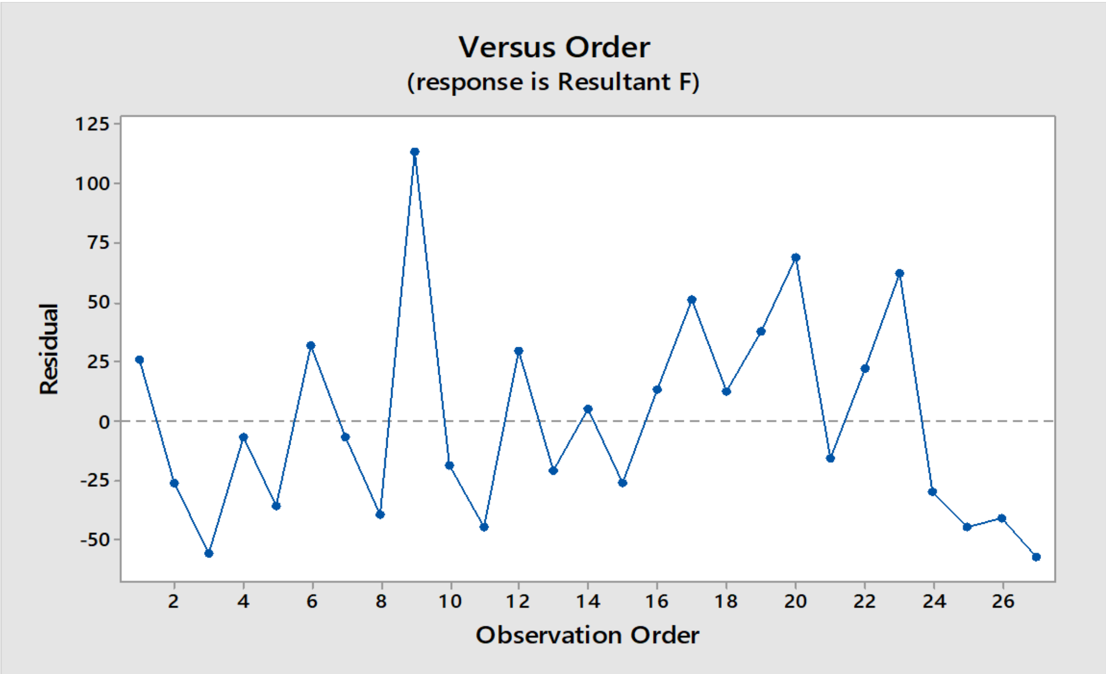

Fig. 4.37(Response is resultant forces relation with residual)

Above figure shows that response is resultant force (F) residual vs observation the pattern of graph is no specific its a random pattern the peak value of residual at 9 order that is 124 residual

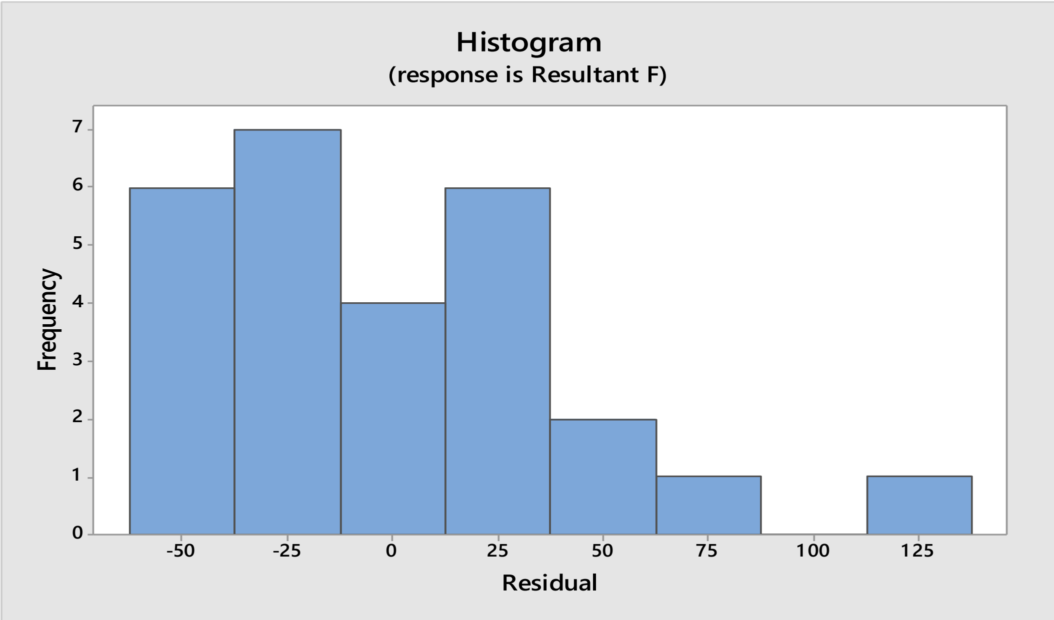

Fig. 4.38 (Response is resultant of forces)

Above graph shows that histogram graph it shows that how frequency is varying according to residual ,so response resultant force(F) random pattern at 100 residual frequency is zero

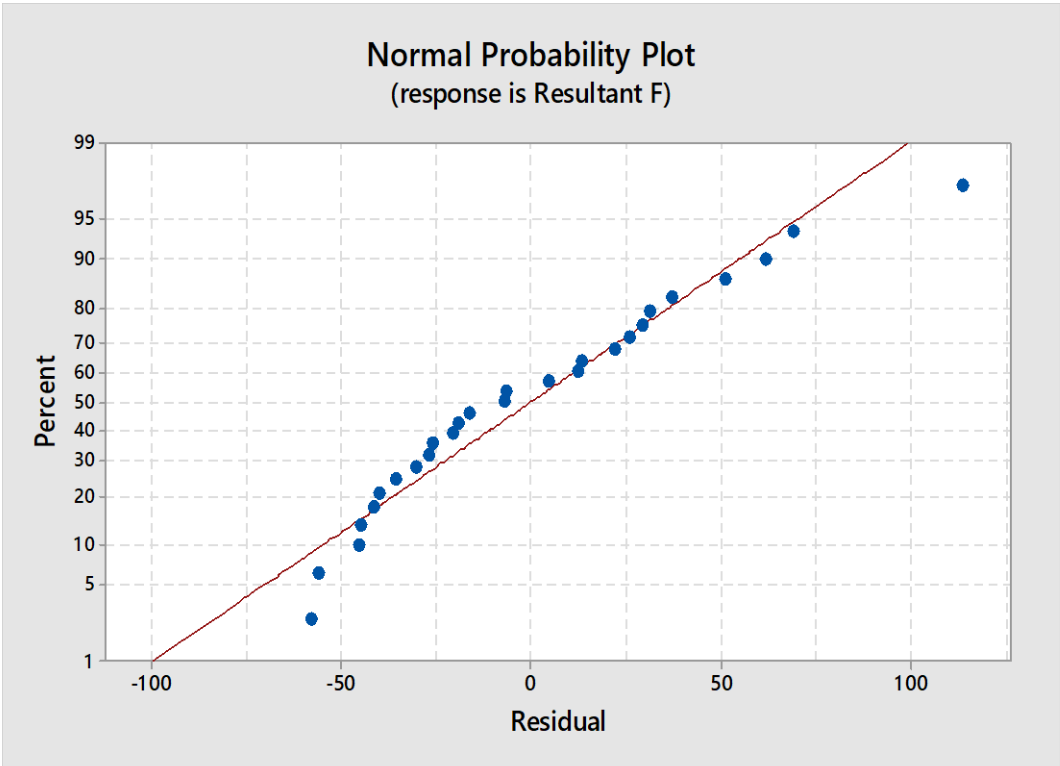

Fig. 4.39 (Normal probability plot of percent and residual)

Above figure shows that the percentage of resultant force (F) varying along the residual line ,that is basically normal probability plot of resultant forces ,residual lies from (-100) to (100)

Regression

Regression Analysis: Resultant F versus Speed, Feed, Depth of cut

Table 4.12 Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	9	149553	16617.0	9.33	0.000
Speed	1	29744	29744.5	16.69	0.001
Feed	1	4159	4159.1	2.33	0.145
Depth of cut	1	628	628.4	0.35	0.560
Speed*Speed	1	17408	17407.7	9.77	0.006
Feed*Feed	1	1038	1037.9	0.58	0.456
Depth of cut*Depth of cut	1	104	104.1	0.06	0.812
Speed*Feed	1	10757	10756.9	6.04	0.025
Speed*Depth of cut	1	3181	3180.8	1.79	0.199
Feed*Depth of cut	1	3121	3121.2	1.75	0.203
Error	17	30290	1781.8		
Total	26	179843			

Regression Equation

Resultant F = -398 + 7.07 Speed + 2496 Feed + 216 Depth of cut - 0.02704 Speed*Speed

- 5261 Feed*Feed - 46 Depth of cut*Depth of cut - 13.41 Speed*Feed

- 1.216 Speed*Depth of cut + 1075 Feed*Depth of cut

Regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modelling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. Regression analysis was employed to derive the predictive equations of the cutting forces, and roundness error

Table 4.13 (Speed,feed,depth of cut, FITS2 and RESI2)

S.No.	Speed	Feed	DOC	Resultant F	FITS2	RESI2
1	36.39	0.05	0.6	84.870	29.182	55.6881
2	36.39	0.05	0.9	79.616	75.915	3.7003
3	36.39	0.05	1.2	88.200	114.319	-26.1189
4	36.39	0.10	0.6	131.846	122.377	9.4685
5	36.39	0.10	0.9	149.591	185.237	-35.6468
6	36.39	0.10	1.2	254.988	239.769	15.2199
7	36.39	0.15	0.6	185.166	189.267	-4.1011
8	36.39	0.15	0.9	198.677	268.255	-69.5779
9	36.39	0.15	1.2	390.281	338.913	51.3679
10	80.29	0.05	0.6	104.635	139.355	-34.7199
11	80.29	0.05	0.9	125.883	170.076	-44.1927
12	80.29	0.05	1.2	238.041	192.467	45.5737
13	80.29	0.10	0.6	182.554	203.104	-20.5504
14	80.29	0.10	0.9	254.611	249.952	4.6591
15	80.29	0.10	1.2	261.680	288.471	-26.7912
16	80.29	0.15	0.6	269.812	240.548	29.2635
17	80.29	0.15	0.9	354.565	303.524	51.0411
18	80.29	0.15	1.2	353.887	358.170	-4.2833
19	125.66	0.05	0.6	118.414	143.682	-25.2679
20	125.66	0.05	0.9	196.978	157.854	39.1234
21	125.66	0.05	1.2	149.911	163.697	-13.7861
22	125.66	0.10	0.6	182.554	176.999	5.5549
23	125.66	0.10	0.9	269.277	207.299	61.9784
24	125.66	0.10	1.2	215.377	229.270	-13.8924
25	125.66	0.15	0.6	168.675	184.011	-15.3357
26	125.66	0.15	0.9	219.354	230.439	-11.0849
27	125.66	0.15	1.2	241.247	268.537	-27.2896

CHAPTER 5

CONCLUSIONS AND FUTURE SCOPE

5.1 Conclusions

5.1.1 Surface roughness

- Speed-high speed give better surface quality , so that speed is 125.66m/min
- Feed-low feed give better surface roughness, so that optimal feed is 0.05mm/rev
- Depth of cut-at low depth of cut give better surface roughness so low depth of cut required that is 0.6mm
- Optimal values of the parameters are –optimal value for better surface roughness is speed (125.66m/min,) feed (0.05mm/rev),depth of cut (0.6mm)

5.1.2 Forces

- Speed-as speed increases from the resultant force first increase upto 240 N then decreases up to195N so at speed 80.29m/min resultant force maximum 240N
- Feed-feed increases resultant force increases up to 269.66N
- Depth of cut-as depth of cut increases resultant force increases 254.6N
- Optimal values of the parameters are –the optimal values of resultant forces are 241.24N at speed80.29m/min,269.66n at feed0.15mm/rev and 254.6N at depth of cut1.2mm

5.2 FUTURE SCOPE

Following are the scope for future research on this topic.

- This research has considered turning spindle speed feed depth of cut forces, material diameter, material thickness, spindle speed and feed rate as dependent variables and thrust force, torque, surface roughness and delamination as dependent variables of study while machining GFRP composites using solid carbide drills. There is an ample scope to consider several factors which were extraneous to this study to name a few, the influence of volume fraction, fiber orientation, turning material etc., and the interactions between these variables could also be studied as the future work.

- The current research has considered three levels in the factors during the selection of factorial combinations in DOE. These levels could be extended beyond the boundaries fixed in this research by selecting different machine and tool specifications for the same material and tool combinations.
- The systematic methodology adopted in this research can be applied for any other combination of tool and material.
- The modeling techniques used in this research may also be used for comparative analysis.

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