**ANALYSIS OF SURFACE ROUGHNESS IN TURNING OF**

**MILD STEEL**

#### A Major Project Submitted in partial fulfillment for the requirement

#### for the award of the degree of

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**In**

Production Engineering

Submitted By:

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**2011**

**Candidate’s declaration**

I, LALIT KUMAR, hereby certify that the work which is being presented in this thesis entitled “**ANALYSIS OF SURFACE ROUGHNESS IN TURNING OF MILD STEEL**” in the partial fulfillment of requirement for the award of degree of **Masters of Engineering** submitted in the **Department of Mechanical Engineering** at **Delhi College Of Engineering**, **Delhi University**, is an authentic record of my own work carried out during a period from July 2010 to June 2011, under the supervision of **Dr. VIPIN,** **Asso. Prof., Department of Mechanical Engineering, Delhi College of Engineering, Delhi.**

The matter presented in this thesis has not been submitted in any other University/ Institute for the award of M.E. Degree.

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**CERTIFICATE**

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

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**ACKNOWLEDGEMENT**

It is a matter of great pleasure for me to present my dissertation report on “**ANALYSIS OF SURFACE ROUGHNESS IN TURNING OF MILD STEEL**”**.** First and foremost, I am profoundly grateful to my guide **Dr. VIPIN,** **Asso. Prof.,** **Mechanical Engineering Department** for his expert guidance and continuous encouragement during all stages of thesis. I feel lucky to get an opportunity to work with him. Not only understanding the subject, but also interpreting the results drawn thereon from the graphs was very thought provoking. I am thankful to the kindness and generosity shown by him towards me, as it helped me morally complete the project before actually starting it.

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**ABSTRACT**

In metal cutting and manufacturing industries, surface finish 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. In this research, 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. Different cutting parameters have different influential on the surface finish. In the experiment conducted in this research, 3 cutting speed, 3 feed and 3 depth of cut were used. Design of experiment, the total set of experiments carried out is 27 sets. At first, the mild steel was undergone chemical composition test using Arc Spectrometer, and was decide that it is be of grade IS: 2062-2006 Grade: E-250 (Fe410W) B . The cutting speed, feed and depth of cut were decide using the suitable range recommended; which were 62.17m/min, 98.09m/min. and 154.74m/min. for cutting speed, 0.2mm, 0.3mm and 0.4mm for depth of cut 0.2mm , 0.25mm and 0.3mm. 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 or lower depth of cut produce better surface finish. The optimum cutting speed, feed and depth of cut in this case were 154.74 m/min , 0.2mm/rev and 0.2mm. Which produced average surface roughness 3.21μm. Cutting speed, feed and depth of cut are a significant parameter in influencing the surface roughness.

**Keywords**: Machining optimization, surface roughness, Taylor Hobson’s Surtronic 3+.

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**Nomenclature**

**Parameter Description**

Ra Parameter of roughness

**The motif (R & W) parameters**

*R*  Average depth of roughness motifs

*R*x Maximum depth of roughness motifs

*A*r Average spacing of roughness motifs

*W*x Maximum depth of waviness motifs

*Rsm* Average spacing of waviness motifs

*P*t Maximum depth of the raw profile

**The “*R*k” family of parameters**

*R*k Depth of the roughness core profile

*R*pk Top portion of the surface to be worn away

*R*vk Lowest part of the surface retaining the lubricant

MR1 Upper limit of the core roughness

MR2 Lowest limit of the core roughness

**Chapter 1**

**1.1 INTRODUCTION**

Lathe machine is the oldest machine tool that is still the most common used machine in the manufacturing industry to produce cylindrical parts. It is widely used in variety of manufacturing industries including aerospace and automotive sectors, where quality of surface plays a very important role in the performance of turning as good-quality turned surface is significant in improving fatigue strength , corrosion resistance , and creep life. Surface roughness also affects several functional attributes of parts, such as wearing , heat transmission , ability of holding a lubricant , coating , or resisting fatigue. Nowadays, roughness plays a significant role in determining and evaluating the surface quality of a product as it affects the functional characteristic.

The product quality depends very much on surface roughness. Decrease of surface roughness quality also leads to decrease of product quality. In field of manufacture, especially in engineering, the surface finish quality can be a considerable importance that can affects the functioning of a component, and possibly its cost. Surface roughness has been receiving attention for many years in the machining industries. It is an important design feature in many situations, such as parts subject to fatigue loads, precision fits, and fastener holes and so on. In terms of tolerances, surface roughness imposes one of the most crucial constraints for the machines and cutting parameters selection in process planning. Manufacturing industries are very much concerned about the quality of their products. They are focused on producing high quality products in time at minimum cost. Surface finish is one of the crucial performance parameters that have to be controlled within suitable limits for a particular process. Therefore, prediction or monitoring of the surface roughness of machined components has been an important area of research. Surface roughness is harder to attain and track than physical dimensions are, because relatively many factors affect surface roughness. Some of these factors can be controlled and some cannot. Controllable 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 variability can not be controlled as easily. Surface roughness also affects several functional attributes of parts, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating or resisting fatigue. Therefore the desired finish surface is usually specified and the appropriate are selected to reach the required quality. Several works have been reported in the broad field of tool condition monitoring. Researchers are trying to develop a robust and accurate model that can find a correlation between the cutting parameters and the surface roughness of the machined products.

**1.2 Types of Roughness**

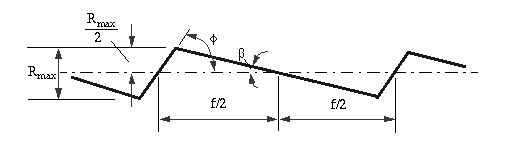
The resultant roughness produced by a machining process can be thought of as the combination of two independent effects: Ideal roughness and Natural roughness.

### 1.2.1 Ideal Roughness

Ideal surface roughness is a function of only feed and geometry. It represents the best possible finish which can be obtained for a given tool shape and feed. It can be achieved 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 φ + cot β)

**Ra = Rmax / 4**

  
f 🡪 Feed

Ф 🡪 Major cutting edge angle

Β 🡪 working minor cutting edge angle

**1.2.2 Surface roughness of machined surfaces**

Surface roughness is caused by:

1. The feed marked or ridges left by the cutting tool, and
2. The fragments of built-up edge shed on the work surface in the process of chip formation. Surface finish can be improved by reducing the height of the feed ridges and the size of the built up edge.

**1.3 Cutting Parameters**

The important cutting parameters discussed here are cutting speed, feed and depth of cut.

**1.3.1 Cutting Speed**

All materials have an optimum Cutting Speed and it is defined 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 spindle Speed required,

**N= 1000 VC /Dπ**

Where:   
N = Spindle Speed (RPM), VC = Cutting Speed of Metal (m/min), D = Diameter of W/p

**1.3.2 Feed**

The term `feed' is used to describe the distance the tool moves per revolution of the work piece and depends largely on the surface finish required. For roughing out a soft material a feed of up to 0.25 mm per revolution may be used. With tougher materials this should be reduced to a maximum of 0.10 mm/rev. Finishing requires a finer feed then what 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. Depth of cut depends upon cutting speed, rigidity of machine tool and tool material etc. Depth of cut normally varies between 1 to 5mm for roughing operation and 0.2 to 1 mm for finishing operation.

**1.3.4 Effect of cutting parameters**

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

Since these cutting parameters will decide about the type of chips which we expect at the time of machining of a single constant material thus we have to analyze them for no such built-up edge chips formation. At the optimum cutting speed at which the effect of built up edge is negligible, (high speed, ductile material) the profile of the cutting edge of the tool is reproduced on the work surface and this ideal surface roughness is mainly dependent on cutting feed. That means for a greater feed the average roughness value is more as compared to the lesser feed. Fig 1.2 shows the relation of feed and roughness while finishing turning aluminum alloys with a diamond tool.



**Fig 1.2** Finish turning aluminum alloy with diamond tool

(Referred R.K. JAIN, Production Technology)

It would be noted that the size of chips cross-sectional area has a large effect on surface finish. Surface finish is poor for large cuts which is desirable from considerable of high tool life and power consumption. Large feed is more detrimental to surface finish than a large depth of cut.

The characteristics in fig.1.3 for finish turning of non-ferrous alloys between depth of cut 0.025 mm and 0.25 mm shows that the roughness is not very much affected at low depth of cut.



**Fig 1.3** Finish turning non-ferrous alloys with feed of 0.01 mm/rev

(Referred R.K. JAIN, Production Technology)

For very high cutting speeds the chances of built up edge reduces thus surface roughness also expected to reduce, while when cutting speed is low built-up formation of chips would increase the surface roughness.

**1.4 CARBON STEEL**

Carbon steel is a metal alloy, a combination of two elements that are iron and carbon, where other elements are present in quantities too small to affect the properties. It is by far the most frequent used steel. The feasibility of using carbon steels depend on whether or not their properties (tensile, yield, and fatigue strength; impact resistance, need for heat treating, etc.) are suitable for parts to be used (Isakov, 2009). Carbon steels may be further classified into 3 major groups: low carbon steel, medium carbon steel and high carbon steel. Standard wrought-steel compositions (for both carbon and alloy steels) are designated by an AISI or SAE four-digit code, the last two digits of which indicate the nominal carbon content.

The carbon-steel grades are:

 10xx: Plain carbon

 11xx: Resulfurized

 12xz: Resulfurized and rephosphorized

 15xx: Nonresulfurized, Mn over 1.0 %

**1.4.1 Low Carbon Steel**

Low carbon steel, also known as mild steel, contains 0.05 % to 0.26 % of carbon (e.g. AISI 1018, AISI 1020 steel). These steels are ductile and have properties similar to iron. They cannot be modified by heat treatment. They are cheap, but engineering applications are restricted to non-critical components and general paneling and fabrication work. These steels cannot be effectively heat treated. Consequently, there are usually no problems associated with heat affected zones in welding process. The surface properties can be enhanced 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 (e.g. AISI 1040, AISI 1045 steel). These steels are highly susceptible to thermal treatments and work hardening. They easily flame harden and can be treated and worked to yield high tensile strengths provided that low ductility can be tolerated. The corrosion resistance of these steels is similar to low carbon steel, although small additions of copper can lead to significant 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 (e.g. AISI 1086, AISI 1090). Cold working is not possible with any of these steels, as they fracture at very low elongation. They are highly sensitive to thermal treatments. Machinability is good, although their hardness requires machining in the normalized condition. Welding is not recommended and these steels must not be subjected to impact loading. They are normally used for components that require high hardness such as cutting tools and blades.

**1.5 PROBLEM STATEMENT**

Surface finish is a quality that is specified by customer for machined parts. There are many parameters that have effect on surface roughness, but most are difficult to quantify adequately. In turning operation, there are many parameters such as cutting speed, depth of cut and feed rate that have great impact on the surface finish. In order to maximize the gains from turning operation, an accurate model of process must be constructed. In this research, an attempt has been made to generate a surface roughness prediction. Besides in manufacturing application, surface roughness is also important in hygienic process applications. For example, system integrity and ease of cleaning/sterilization is dependent upon valve design and internal surface finish. A smooth surface finish reduces the risk of system contamination, and increases the speed of cleaning and sterilization. All these while, there are numbers of studies are done to investigate the general effects of feed, cutting speed and depth of cut on the surface roughness. Thus, in this research, a graphical study [1. Profile Curve 2.Bearing Area Curve 2.1. R.K. Parameters 2.2. Abbott-Firestone Curve 3. Roughness And Waviness Motifs (ISO 12085)] has been carried out to generate the optimum surface finish on turning operation by using cutting speed, feed and depth of cut as parameters. The material that will be used is mild steel (IS: 2062-2006 Grade: E-250 (Fe410W) B ).

**Chapter 2**

**LITERATURE REVIEW**

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

* ***Mike Stewart*** [1] tribologist have demonstrated that an ideal bearing surface is a smooth one with relatively deep scratches-to hold and distribute lubricant, but quantifying and specifying these surfaces has always been a problem. The normalized abscissa and highest peak reference commonly used for plotting the bearing area curve limits its use for quantitative analysis, but when plotted on an absolute scale with a mean line reference, it becomes a powerful analytical tool for evaluating and specifying bearing surfaces. A recent attempt to standardize the Bearing Area Parameters appears in the DIN 4776, with the introduction of the R, Rvk, Rpk parameters. These parameters, now gaining interest in America, encompass a good crossection of the ideas behind most of the evaluations done up to their introduction. These parameters may be well suited for process control, but the engineer must understand the implications of the bearing area curve and how these parameters are derived from the curve before putting them into use.
* ***Prof. Dr.-lng. M. Dietzsch*** [2] worked on surface roughness and waviness. The MOTIF-method (ISO 12085) is a graphical evaluation with the complete description of roughness and waviness with merely 7 parameters and the evaluation based on the upper envelope line, which have an importance for the functional behaviour. Roughness and waviness can be evaluate directly based on the diagram of the unfiltered profile. The parameter of the MOTIF-method reflects the geometrical dimension of the profile irregularities. The separation of roughness from waviness happens absolute sharp with an automatically

adjustment to the width of the characteristic irregularities of the profile. The MOTIF-method finds out within these limits the horizontal and vertical properties of the essential profile irregularities without elimination of important profile points. It is very well suited 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.

* ***Minodora Rîpă et al*** [3] worked on the majority of the roughness parameters allow general description of the surface topography. For tribological characterisation of surface topography, analyses based on Abbott-Firestone Curve give useful information about some special functioning properties as bearing, sealing and lubricant retaining capabilities. The paper presents the results of roughness analyses for the worn surfaces of steel rollers, obtained after rolling/sliding wear tests. Studies based on zoning of Abbott-Firestone curve give the best results for the surfaces characterized by a depth of the worn layer less than maximum roughness height. Topographical studies are also necessary for cases when wear is dominated by plastic deformation.
* ***Benardos P.G. and Vosniakos G.-C.*** [4]reviewed various methodologies and practices that are being employed for the prediction of surface roughness. The resulting benefits allow for the manufacturing process to become more productive and competitive and at the same time to reduce any re-processing of the machined workpiece so as to satisfy the technical specifications. Each approach with its advantages and disadvantages is outlined and the present and future trends are discussed. As is evident from the referenced papers, in recent years there has been a great deal of research activity in the field and the results that have been produced are good. The trend that is formed encourages more automated systems building for on-line monitoring, measuring or control and is mainly driven by the fact that the processes themselves have been automated to a great extent. All the methodologies that are presented here can exhibit advantages and disadvantages when compared to one another, but given this trend the most promising seem to be the theoretical and the AI approaches.
* ***Ulvi Seker et al*** [5] worked on ductile iron due to its enhanced strength, ductility and toughness, ductile iron has poor machining properties when compared to flake graphite cast iron. However, when a steel part is replaced with ductile iron, better machinability is considered to be the most important gain. This study presents the results of machining tests of ductile irons (DIs) alloyed with Ni and Cu at various amounts to determine the effect of their microstructures and mechanical properties on cutting forces and surface roughness. Six different groups of ductile iron specimens alloyed with various amounts of Ni and Cu were subjected to machining tests and their machinability were investigated based on cutting forces and surface roughness criteria. The results show that alloying ductile iron with Ni and Cu at various amounts affected cutting forces developed during turning and surface finish of the machined components significantly, in terms of both criteria, the best results obtained were for the specimen alloyed with 0.7% Ni and 0.7% Cu. In this study, among machinability criteria, only cutting forces and surface roughness were investigated.
* ***Petropoulos G. et al*** [6] worked on the surface motif combination, ISO 12085:1996, is a method of analyzing surface texture alternatively to the central line system ‘M’. It gives a graphical evaluation of surface profile using mainly six parameters without filtering waviness from roughness. Another functional roughness characterization is introduced by the DIN 4776 and ISO 13565-2 standards through the ‘’Rk’’ parameters, which describe the shape of the relevant Abbott curves. This study presents the application of both the aforementioned methods in the analysis of turned textures carrying out turning tests for cutting conditions varied over a representative range. The workpiece material was a 304 stainless steel turned by a P30 cemented carbide tool. Close correlation was detected between many of the parameters considered and primarily feed and cutting speed, a fact that led to the development of regression models. Comparisons made to the variation of popular ‘’M’’ system parameters indicate that motif parameters provide an alternative way for controlling the turning process and determining optimal cutting conditions. Both standards and especially the ‘’Rk’’ group are mainly oriented to functional topographic characterization of engineering surfaces. The present study proved that cutting conditions in turning influence the values of most of these parameters in a definite way, permitting

the formulation of statistical regression models showing from good to excellent correlation.

* ***Yusuf Sahin and Riza Motorcu A.*** [7]developed a surface roughness model for turning of mild steel with coated carbide tools. The model is developed in terms of cutting speed, feed rate and depth of cut, using response surface methodology. First-order and second-order model predicting equations for surface roughness have been established by using the experimental data. Surface roughness increased with increasing the feed rate but decreased with increasing the cutting speed and the depth of cut, respectively. In addition, analysis of variance for the second-order model shows that the interaction terms and the square terms are statistically insignificant. Moreover, it is seen that the first-order effect of feed rate and cutting speed is significant while depth of cut is insignificant. The established equations clearly show that the feed rate was main influencing factor on the surface roughness. It increased with increasing the feed rate but decreased with increasing the cutting speed and the depth of cut, respectively. Among the other parameters, depth of cut was found to be more insensitive than that of the cutting speed. However, v and t had a similar negative effect on surface finish.
* ***S. Thamizhmanii et al*** [8], worked on the analysis of optimum cutting conditions to get lowest surface roughness in turning SCM 440 alloy steel by Taguchi method. Taguchi method has shown that the depth of cut has significant role to play in producing lower surface roughness followed by feed. The Cutting speed has lesser role on surface roughness from the tests. The results obtained by this method will be useful to other researches for similar type of study and may be eye opening for further research on tool vibrations, cutting forces etc. This research gives how to use Taguchi’s parameter design to obtain optimum condition with lowest cost, minimum number of experiments and industrial engineers can use this method. The research can be extended by using tool nose radius, lubricant, material hardness, etc as parameters.
* ***Petropoulos G.P.*** [9] worked on complexity of machined surface profiles and the contemporary demands for functional characterization, multi- parameter analysis of roughness is recommended by international surface metrology standards, as well as by recent research studies. This article is aimed at presenting a retrospect of works reported by the author on aspects of machined surfaces along with modeling of various texture parameters. A multi-parameter analysis of engineering surface texture is a must owing to the high precision and functional requirements for critical applications existing in the contemporary machining of components.
* ***Thamizhmanii S. et al*** [10] studied the application of the Taguchi method parameter design to optimize the surface roughness, tool wear and cutting force by hard turning process. The Taguchi parameter design method is an efficient method in which response variable can be optimized, given various controls and using fewer experimental runs. Hard turning is the latest trend in all manufacturing industries and it is a profitable alternative to grinding. The hard turning removes unwanted material in a single cut rather than grinding in order to reduce process time, set up time, operating cost, surface roughness and to produce components economically. The experimental results show that there is a good agreement between surface roughness and flank wear both by equations and experiments by Taguchi method. The study shows that it is an efficient method for determining the optimum operating parameter to achieve lower surface roughness by Taguchi parameter design process.
* ***Lalwani*  *D.I. et al*** [11], studied 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. 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. The suggested models of cutting forces and surface roughness adequately

map within the limits of the cutting parameters considered. the feed rate provides primary contribution and influences most significantly on the surface roughness.

* ***Palanikumar K. et al*** [12], worked on Fibre-reinforced plastic (FRP) composite materials This paper presents a study of influence of cutting parameters on surface roughness parameters such as *R*a, *R*t, *R*q, *R*p and *R*3z in turning of glass fibre reinforced composite materials. Empirical models are developed to correlate the machining parameters with surface roughness. Analysis of experimental results is carried out through area graphs and three-dimensional surface plots. The surface roughness increases with the increase of feed rate and almost decreases with the increase of cutting speed.
* ***Paulo Davim*** ***J.*** *et al* [13] , developed a surface roughness prediction models using artificial neural network (ANN) to investigate the effects of cutting conditions during turning of free machining steel. The ANN model of surface roughness parameters (*R*a and *R*t) is developed with the cutting conditions such as feed rate, cutting speed and depth of cut as the affecting process parameters. The analysis reveals that cutting speed and feed rate have significant effects in reducing the surface roughness, while the depth of cut has the least effect.
* ***Chen Lu*** [14], studied the surface profile and roughness of a machined workpiece. The author’s present work—prediction of surface profile using RBF neural network and future trend are also introduced. The RBF neural network trained with adaptive-adjusting parameter was found to be the optimal network for the prediction of surface profile. The shape, amplitude and trend of surface profile machined by turning process could be predicted with a good consistency with the actual profile.
* ***Grzesik W. and Brol* *S.*** [15], worked on the surface profiles generated in longitudinal turning operations were characterized using continuous wavelet transform (CWT) and normalized fractal dimension *D*n. The results of the CWT as a function of profile and momentary wavelet length are presented. It is concluded that CWT can be useful for the analysis of the roughness profiles generated by cutting processes. Moreover, the wavelet

transform together with fractal dimension can be capable of the detection of local self-similarity in the surface profile. In order to aggregate information about amplitudes and lengths of profile constituent’s distribution, analysis of at least two CWT by means of different wavelets is necessary.

* ***Childs T.H.C.et al*** [16**],** worked on surface minimum roughnesses, achievable mainly with cemented carbide but also with single crystal diamond round nosed turning and facing inserts, has been experimentally studied, machining aluminium on engineering and precision lathes. Insert edge sharpness and roughness measurements and characteristic variations with feed rate of machined surface profile are presented. When machine tool limits are avoided, Rz values down to 0.02 times the insert edge radii have been obtained.
* ***Adriana Carmen Cîrstoiu*** [17] worked on experimental determination of the influence of the cutting tool nose radius on surfaces roughness in case of external turning. A roughness evaluation by its correlation with Abbott-Firestone curve and statistical distribution of the amplitudes of roughness profiles has been undertaken in the frames of this paperwork. By studying the bearing area ratio and the Abbott-Firestone curve, we notice that as the roughness decreases, the lift (bearing area ratio) increases. If the nose radius increases, to get the same rate of lift, we need a cutting depth of the surface becoming less. Therefore, improving the quality of the surfaces, turning them with cutting tools with larger nose radii, lead to increased bearing surface Rsk has positive values, leading to an asymmetrical profile, shifted to the right, indicating a sharp profile of a less wear resistant surface. Bearing surface should have negative skew. Rku has values between 2 and 3, the amplitude distribution curve profile having no significant deviations from normal distribution.
* ***Adeel H et al*** [18] worked on experimental study is to optimize the cutting parameters using two performance measures, workpiece surface temperature and surface roughness. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in turning operation.The

experimental results showed that the workpiece surface temperature can be sensed and used effectively as an indicator to control the cutting performance and improves the optimization process. Thus, it is possible to increase machine utilization and decrease production cost in an automated manufacturing environment.

* ***Dr. E. Daniel Kirby [19]*** *worked on*lowest surface roughness, which usually requires the lowest possible feed rate and therefore a long cutting time. This study seeks an *actual* target surface roughness value, which may allow for a higher feed rate depending upon that specified target. In using the variation of the *nominal-the-best* signal to noise formula that uti­lizes MSD, variation about a specified (ideal) value is explored and sought to be minimized. It is demonstrated here that Taguchi Parameter Design can be used to determine the optimal levels of controlled parameters to meet a quality target without sacrificing productivity. By practic­ing Taguchi Parameter Design projects, one can gain experience and knowledge in industrial DOE and statistics, as well as the in-depth study of manufactur­ing processes. Furthermore, just as is found in a production environment, this provides an efficient project in an academic environment as well.
* ***Khaider Bouacha et al*** [20] worked on experimental study of hard turning with CBN tool. The relationship between cutting parameters (cutting speed, feed rate and depth of cut) and machining output variables (surface roughness, cutting forces) through the response surface methodology (RSM) are analysed and modeled. The combined effects of the cutting parameters on machining output variables are investigated while employing the analysis of variance (ANOVA). The quadratic model of RSM associated with response optimization technique and composite desirability was used to find optimum values of machining parameters with respect to objectives (surface roughness and cutting force values). The depth of cut exhibits maximum influence on cutting forces as compared to the feed rate and cutting speed. During tool–workpiece interaction, it was found that the machined material hardness plays a dominant role in the variation of the cutting forces than cutting speeds. Also, the higher the feed rate and cutting depth, the higher the cutting force, whereas the higher the cutting speed, the lower the cutting force. The depth of cut exhibits maximum influence on cutting forces as compared to the feed

rate and cutting speed. Moreover, it is noted that the thrust force is the largest force component regardless the cutting conditions, and it is most sensitive to workpiece hardness, negative rake angle and tool wear evolution.

* ***Esteves Correia A. and Paulo Davim J.*** [21] worked on surface roughness using wiper inserts, which are increasingly being utilized in last years. This study considers the influence of the wiper inserts when compared with conventional inserts on the surface roughness obtained in turning. With wiper inserts and high feed rate it is possible to obtain machined surfaces with Ra < 0.8 lm (micron). Consequently it is possible to get surface quality in workpiece of mechanics precision without cylindrical grinding operations. Finish machining with wiper inserts provide a similar roughness when compared with machining with a low feed rate using conventional inserts. With high feed rate conventional inserts present high values of surface roughness when compared with wiper inserts.

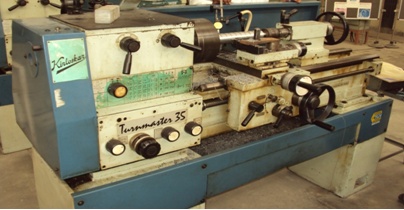
**Chapter 3**

**EXPERIMENT 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 lathe**

The Lathe machine is the oldest machine tool that is still the most common used machine in the manufacturing industry to produce cylindrical parts. For instance, shaft, axel and bearing, are crucial in machining motions. It is widely used in variety of manufacturing Industries including aerospace and automotive sectors, where quality of surface plays a very important role in the performance of turning as good-quality turned surface is significant in improving fatigue strength, corrosion resistance, and creep life. Surface roughness also affects several functional attributes of parts, such as wearing, heat transmission, ability of holding a lubricant, coating, or resisting fatigue. Nowadays, roughness plays a significant role in determining and evaluating the surface quality of a product as it affects the functional characteristic.



**Figure: 3.1 Lathe Machine**

**Table 3.1 Lathe specifications**

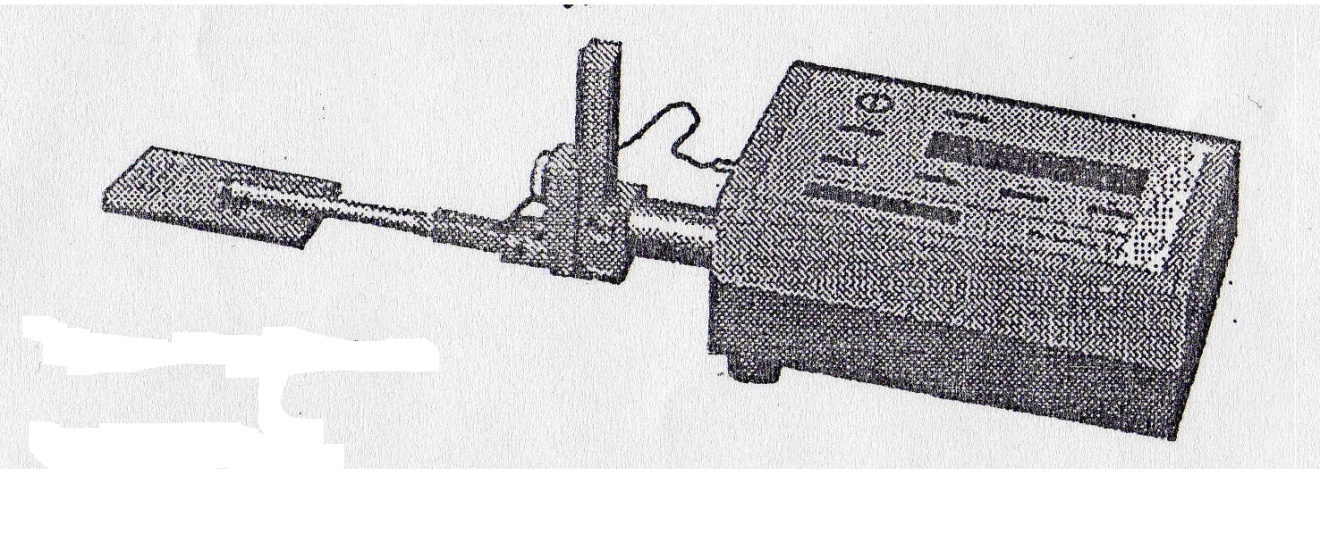
|  |  |
| --- | --- |
| **Model** | **Turn master-3S** |
| Swing over bed | 350mm |
| Swing over cross slide | 200mm |
| Distance between centers | 800mm |
| Movement of cross-slide | 200mm |
| Spindle inside diameter | 50mm |
| Standard cutting tool size | 20\*20mm |
| Spindle Speed | 45 to 1120 rpm |
| Feed (mm/rev) | 0.045-0.63mm/rev. |
| Spindle Motor | 2.2 KW / 3HP |
| Power Supply | 415V,3 Phase, 50 cycle, AC supply |
| Net weight | 800Kg. |
| Floor Space required | 2000\* 850mm |

**3.2 Surface Roughness Measuring Instrument**

The Surtronic 3+ is a portable, self-contained instrument for the measurement of surface texture and is suitable for use in both the workshop and laboratory. Parameters available 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 an optional 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.



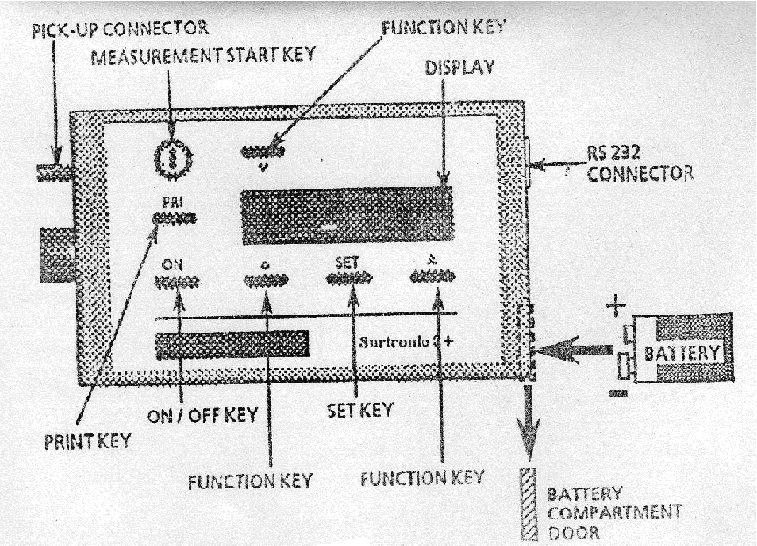
**Figure: 3.2** Surface roughness measurement apparatus

(Referred from Instrument Manual)

**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, computing 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 contains a drive motor which traverses the pickup across the surface to be measured. The measuring stroke always starts from the extreme outward positions. At the end of the measurement the pick up returns to this position ready for the next measurement. The traverse length is determined from selections of cut-off (Lc) or length (Ln).

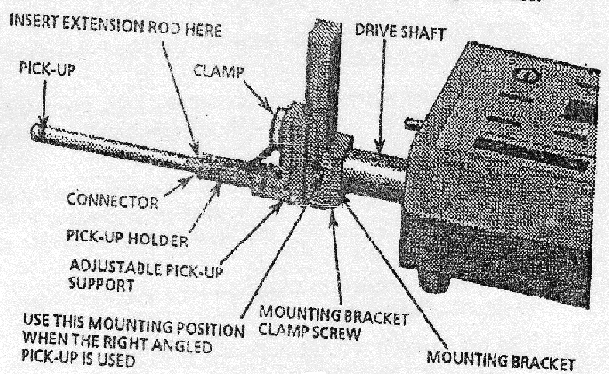


**Figure: 3.3** Display Transverse Unit (Referred from Instrument Manual)

**Pick-Up Mounting Components**

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

**Mounting Bracket**: This is clamped 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.



**Figure: 3.4** Mounting Bracket (Referred from Instrument Manual)

**Adjustable Support**: this can be clamped at any positions on the slide of the mounting bracket to provide pick-up height adjustment.

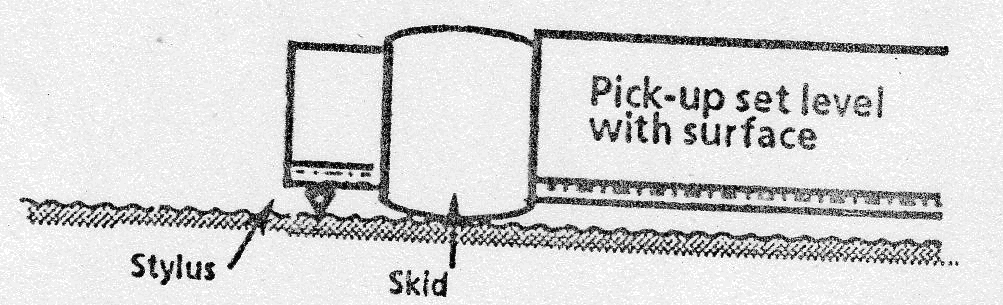
**Pick-up Holder**: This fits into the crutch of the pick-up support and is held in place by a spring plunger.

**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.

**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 changed 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.

**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.



**Figure: 3.5** Pick-up (Referred from Instrument Manual)

**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 DIP-Switch.

Parameters: Ra, Rq, Rz (DIN), Ry and Sm.

Calculations Time: Less Than Reversal Time Or 2 Sec Which Ever Is The Longer.

**3.3 Work piece material**

Lathe made Kirloskar was available for turning.The chuck holding the work piece was self centering type. Material was selected to ensure consistency of the alloy, which is a Mild Steel [as per IS:2062-2006 Grade E-250 (Fe410W) B] made in the form of bars with the size of diameter 50mm and 250mm length so as to fit under the chuck. To more closely replicate typical finish turning processes and to avoid excessive vibrations due to work piece dimensional inaccuracies and defects, each work piece was rough-cut just prior to the measured finish cut.

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 taken 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.

**3.4 Cutting Tool Material**

The cutting tool which is used for the present work was a carbide tip-KC5525. The basic properties of carbide tools have high 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/cm2 ,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 700oC and have high wear resistance [22]. The tool used was cemented carbide insert type with tip radius 0.8mm. The work piece material was mild steel grade IS: 2062-2006 Grade: E-250 (Fe410W) B with the chemical composition as under:

**TABLE 3.2** (Chemical Composition of Work Piece)

|  |  |  |
| --- | --- | --- |
| **Element** | **Requirement Specification (As per IS:2062-2006**  **Gr. E-250 (Fe410W) B)** | **Weight %** |
| C | 0.22 Max | 0.2012 |
| Mn | 1.5 Max | 0.4936 |
| Si | 0.40 Max | 0.1537 |
| P | 0.045 Max | 0.0304 |
| S | 0.045 Max | 0.0323 |
| Cr. |  | 0.1961 |
| Mo |  | 0.0146 |
| Ni |  | 0.0870 |
| Hardness | - | 160 BHN |

Wiper inserts used in this study can provide significant advantages in a rough turning operations. The slightly higher cutting forces generated by the wiper insert is not a factor in a roughing operation. Consistent results in finishing operations are greatly influenced by the condition of the workpiece material before the last pass is taken. If chatter exists after the rough pass, it will continue to the finish pass and be very difficult to remove. Thus, if a wiper insert is used in the turning operation prior to finishing, the workpiece will have a superior surface for the final cut by the finishing tool. This enhanced surface before finishing will improve the ability of the finishing insert to hold size longer and cut more accurately. Using wiper inserts for roughing will improve surfaces for better finishing cuts, regardless if a wiper insert is used for the final finishing cuts. The wiper insert geometry also provides additional insert strength for longer tool life. Using a wiper insert for rough or finish turning should be your first consideration. However , do the research before you select a wiper insert as your tool of choice. Optimize productivity by increasing feed rates while maintaining surface finish, or double the feed rate while maintaining finish requirements.

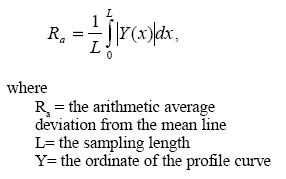
**3.5 Measurement of Surface Roughness**

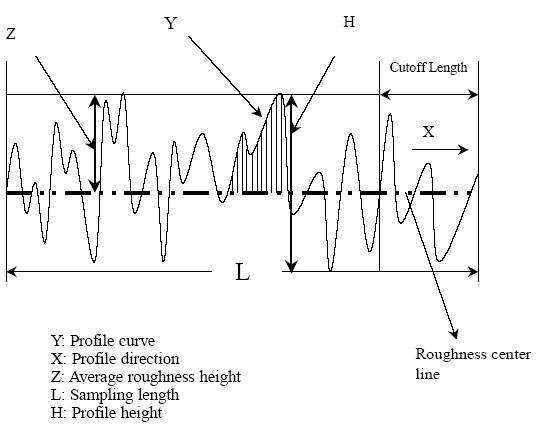
Inspection and assessment of surface roughness of machined work pieces can be carried out by means of different measurement techniques. These methods can be ranked into the following classes:

* [Direct measurement methods](http://www.mfg.mtu.edu/cyberman/quality/metrology/surface.html#para21#para21)
* [Comparison based techniques](http://www.mfg.mtu.edu/cyberman/quality/metrology/surface.html#para22#para22)
* [Non contact methods](http://www.mfg.mtu.edu/cyberman/quality/metrology/surface.html#para23#para23)

**3.5.1 Direct Measurement Methods**

Direct methods access surface finish by means of stylus type devices. Measurements are obtained 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 calculate the roughness parameters. The parameter Ra is used here.





**Figure 4.6** (Measurement of Surface roughness by Stylus)

**3.5.2 Comparison Based Techniques**

Comparison techniques use specimens of surface roughness 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 surface roughness Ra>1.6 micron.

**3.5.3 Non Contact Methods**

In it a rough surface is illuminated 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 surface roughness can be defined and calculated

In these experiments direct measurement method has been used i.e. stylus type surface roughness meter was used to measure the surface roughness of the specimen. There were two main reasons behind selecting stylus type surface roughness; one is its easy availability and other is the ease with which it can be operated. The instrument used in these experiments is a product of precision devices.

**3.6 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 3.3** (Process Parameters and Their Levels)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Process parameters** | **Process designation** | **Levels** | | |
| 1 | 2 | 3 |
| **Speed (m/min)** | A | 62.17 | 98.09 | 154.74 |
| **Depth (mm)** | B | 0.2 | 0.25 | 0.3 |
| **Feed (mm/rev)** | C | 0.2 | 0.3 | 0.4 |

**Chapter 4**

### ANALYSIS OF DATA

### 4. Experiment conducted as per Table 4.1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| S.No. | Diameter | RPM | V | D.O.C. | Feed | |
|  | (mm) |  | m/min | mm | m/min | mm/rev |
| **1** | 44 | 450 | 62.17 | 0.20 | 90 | 0.2 |
| **2** | 44 | 710 | 98.09 | 0.20 | 142 | 0.2 |
| **3** | 44 | 1120 | 154.74 | 0.20 | 224 | 0.2 |
| **4** | 44 | 450 | 62.17 | 0.25 | 90 | 0.2 |
| **5** | 44 | 710 | 98.09 | 0.25 | 142 | 0.2 |
| **6** | 44 | 1120 | 154.74 | 0.25 | 224 | 0.2 |
| **7** | 44 | 450 | 62.17 | 0.30 | 90 | 0.2 |
| **8** | 44 | 710 | 98.09 | 0.30 | 142 | 0.2 |
| **9** | 44 | 1120 | 154.74 | 0.30 | 224 | 0.2 |
| **10** | 44 | 450 | 62.17 | 0.20 | 135 | 0.3 |
| **11** | 44 | 710 | 98.09 | 0.20 | 213 | 0.3 |
| **12** | 44 | 1120 | 154.74 | 0.20 | 336 | 0.3 |
| **13** | 44 | 450 | 62.17 | 0.25 | 135 | 0.3 |
| **14** | 44 | 710 | 98.09 | 0.25 | 213 | 0.3 |
| **15** | 44 | 1120 | 154.74 | 0.25 | 336 | 0.3 |
| **16** | 44 | 450 | 62.17 | 0.30 | 135 | 0.3 |
| **17** | 44 | 710 | 98.09 | 0.30 | 213 | 0.3 |
| **18** | 44 | 1120 | 154.74 | 0.30 | 336 | 0.3 |
| **19** | 44 | 450 | 62.17 | 0.20 | 180 | 0.4 |
| **20** | 44 | 710 | 98.09 | 0.20 | 284 | 0.4 |
| **21** | 44 | 1120 | 154.74 | 0.20 | 448 | 0.4 |
| **22** | 44 | 450 | 62.17 | 0.25 | 180 | 0.4 |
| **23** | 44 | 710 | 98.09 | 0.25 | 284 | 0.4 |
| **24** | 44 | 1120 | 154.74 | 0.25 | 448 | 0.4 |
| **25** | 44 | 450 | 62.17 | 0.30 | 180 | 0.4 |
| **26** | 44 | 710 | 98.09 | 0.30 | 284 | 0.4 |
| **27** | 44 | 1120 | 154.74 | 0.30 | 448 | 0.4 |

### 4.1 Graphical analysis for variable speed at constant feed (0.2mm/rev) and depth of cut (0.2mm)

### 4.1.1 450rpm feed 0.2mm/rev. D.O.C 0.2mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

4.1.2 710rpm feed 0.2mm/rev. D.O.C 0.2mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

4.1.3 1120rpm feed 0.2mm/rev. D.O.C 0.2mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

1. **Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.1.1 Figure 4.1.2**

**Figure 4.1.3 Figure 4.1.4**

**Figure 4.1.5 Figure 4.1.6**

**Figure 4.1.7 Figure 4.1.8**

* **From Fig. 4.1.1 It is seen that with increase in speed there is decrease in Ar (Mean spacing of roughness) till 98.09 m/min then it stabilize further ,it is also seen that with increase in speed there is decrease in Rsm (Mean width of profile ) till 98.09 m/min, then it starts increasing.**
* **From fig. 4.1.2 it is seen that with increase in speed there is decrease in R (Mean depth of roughness) ,it is also seen that with increase in speed there is gradual decrease in Ra (Mean roughness parameter ) .**
* **From fig. 4.1.3 it is seen that with increase in speed there is decrease in both Rx (Mean depth of profile irregularity) and Pt (Max. peak to valley height),it is also seen that reduction in Pt is more then Rx.**
* **From fig. 4.1.4 it is seen that with increase in speed there is gradual decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.1.5 it is seen that with increase in speed there is steep decrease in Rk (core roughness) from 62.17m/min to 98.09m/min, then it starts decreasing linearly .**
* **From Fig. 4.1.6 It is seen that with increase in speed there is increase in MR1 (Material component MR1) and reaches to a max value at 98.09 m/min then it start decreasing with increase in speed. It is also seen that with increase in speed there is decrease in MR2 (Material component MR2) .**
* **From Fig. 4.1.7 It is seen that with increase in speed there is increase in Rvk (Reduced valley height) and with increase in speed there is decrease in Rpk (Reduced peak height) .**
* **From fig. 4.1.8 it is seen that with increase in speed there is decrease in Wx (Maximum depth of waviness).**

### 4.2 Graphical analysis for variable speed at constant feed(0.2mm/rev) and depth of cut(0.25mm)

4.2.1 450rpm feed 0.2mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

4.2.2 710rpm feed 0.2mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

4.2.3 1120rpm feed 0.2mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.2.1 Figure 4.2.2**

**Figure 4.2.3 Figure 4.2.4**

**Figure 4.2.5 Figure 4.2.6**

**Figure 4.2.7 Figure 4.2.8**

* **From Fig. 4.2.1 It is seen that with increase in speed there is decrease in Ar (Mean spacing of roughness) till 98.09 m/min then it increases further ,it is also seen that with increase in (V) cutting speed there is decrease in Rsm (Mean width of profile ).**
* **From fig. 4.2.2 it is seen that with increase in (V) cutting speed there is decrease in R (Mean depth of roughness) ,it is also seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.2.3 it is seen that with increase in (V) cutting speed there is decrease in both Rx (Mean depth of profile irregularity) and Pt (Max. peak to valley height).**
* **From fig. 4.2.4 it is seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.2.5 it is seen that with increase in (V) cutting speed there is increase in Rk (core roughness) from 62.17m/min to 98.09m/min, then it starts decreasing.**
* **From Fig. 4.2.6 It is seen that with increase in (V) cutting speed there is decrease in MR1 (Material component MR1). It is also seen that with increase in (V) cutting speed there is decrease in MR2 (Material component MR2) till 98.09 m/min then it increases further.**
* **From Fig. 4.2.7 It is seen that with increase in (V) cutting speed there is increase in Rvk (Reduced valley height) till 98.09 m/min then it decreases and with increase in (V) cutting speed there is decrease in Rpk (Reduced peak height) .**
* **From fig. 4.2.8 it is seen that with increase in (V) cutting speed there is decrease in Wx (Maximum depth of waviness).**

### 4.3 Graphical analysis for variable speed at constant feed (0.2mm/rev) and depth of cut (0.3mm)

4.3.1 450rpm feed 0.2mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.3.2 71**0rpm feed 0.2mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.3.3 112**0rpm feed 0.2mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.3.1 Figure 4.3.2**

**Figure 4.3.3 Figure 4.3.4**

**Figure 4.3.5 Figure 4.3.6**

**Figure 4.3.7 Figure 4.3.8**

* **From Fig. 4.3.1 It is seen that with increase in (V) cutting speed there is increase in Ar (Mean spacing of roughness) till 98.09 m/min then it decreases further ,it is also seen that with increase in (V) cutting speed there is decrease in Rsm (Mean width of profile ).**
* **From fig. 4.3.2 it is seen that with increase in (V) cutting speed there is decrease in R (Mean depth of roughness) ,it is also seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.3.3 it is seen that with increase in (V) cutting speed there is increase in Rx (Mean depth of profile irregularity) till 98.09 m/min then it decreases further and Pt (Max. peak to valley height) also decrease.**
* **From fig. 4.3.4 it is seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.3.5 it is seen that with increase in (V) cutting speed there is decrease in Rk (core roughness).**
* **From Fig. 4.3.6 It is seen that with increase in (V) cutting speed there is increase in MR1 (Material component MR1) and reaches to a max value at 98.09 m/min then it start decreasing with increase in cutting speed. It is also seen that with increase in (V) cutting speed there is decrease in MR2 (Material component MR2) .**
* **From Fig. 4.3.7 It is seen that with increase in (V) cutting speed there is increase in both Rvk (Reduced valley height) & Rpk (Reduced peak height) and reaches to a max value at 98.09 m/min then it start decreasing with increase in cutting speed.**
* **From fig. 4.3.8 it is seen that with increase in (V) cutting speed there is decrease in Wx (Maximum depth of waviness).**

### 4.4 Graphical analysis for variable speed at constant feed (0.3mm/rev) and depth of cut (0.2mm)

### 4.4.1 450rpm feed 0.3mm/rev. D.O.C 0.20mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.4.2 71**0rpm feed 0.3mm/rev. D.O.C 0.20mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.4.3 112**0rpm feed 0.3mm/rev. D.O.C 0.20mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.4.1 Figure 4.4.2**

**Figure 4.4.3 Figure 4.4.4**

**Figure 4.4.5 Figure 4.4.6**

**Figure 4.4.7 Figure 4.4.8**

* **From Fig. 4.4.1 It is seen that with increase in (V) cutting speed there is decrease in Ar (Mean spacing of roughness) , it is also seen that with increase in (V) cutting speed there is decrease in Rsm (Mean width of profile ) till 98.09 m/min then it increases further.**
* **From fig. 4.4.2 it is seen that with increase in (V) cutting speed there is decrease in both R (Mean depth of roughness) and Ra (Mean roughness parameter ).**
* **From fig. 4.4.3 it is seen that with increase in (V) cutting speed there is decrease in both Rx (Mean depth of profile irregularity) and Pt (Max. peak to valley height).**
* **From fig. 4.4.4 it is seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.4.5 it is seen that with increase in (V) cutting speed there is decrease in Rk (core roughness).**
* **From Fig. 4.4.6 It is seen that with increase in (V) cutting speed there is increase in MR1 (Material component MR1). It is also seen that with increase in (V) cutting speed there is decrease in MR2 (Material component MR2) .**
* **From Fig. 4.4.7 It is seen that with increase in (V) cutting speed there is increase in Rvk (Reduced valley height) till 98.09 m/min then it decreases further & It is also seen that with increase in (V) cutting speed there is decrease in Rpk (Reduced peak height).**
* **From fig. 4.4.8 it is seen that with increase in (V) cutting speed there is decrease in Wx (Maximum depth of waviness).**

### 4.5 Graphical analysis for variable speed at constant feed(0.3mm/rev) and depth of cut(0.25mm)

**4.5.1 45**0rpm feed 0.3mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.5.2 71**0rpm feed 0.3mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.5.3 112**0rpm feed 0.3mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.5.1 Figure 4.5.2**

**Figure 4.5.3 Figure 4.5.4**

**Figure 4.5.5 Figure 4.5.6**

**Figure 4.5.7 Figure 4.5.8**

* **From Fig. 4.5.1 It is seen that with increase in (V) cutting speed there is decrease in Ar (Mean spacing of roughness) , it is also seen that with increase in (V) cutting speed there is increase in Rsm (Mean width of profile ) till 98.09 m/min then it decreases further.**
* **From fig. 4.5.2 it is seen that with increase in (V) cutting speed there is decrease in both R (Mean depth of roughness) and Ra (Mean roughness parameter ).**
* **From fig. 4.5.3 it is seen that with increase in (V) cutting speed there is decrease in Rx (Mean depth of profile irregularity) and increase in Pt (Max. peak to valley height) till 98.09 m/min then it decreases.**
* **From fig. 4.5.4 it is seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.5.5 it is seen that with increase in (V) cutting speed there is decrease in Rk (core roughness).**
* **From Fig. 4.5.6 It is seen that with increase in (V) cutting speed there is decrease in MR1 (Material component MR1). It is also seen that with increase in (V) cutting speed there is increase in MR2 (Material component MR2) .**
* **From Fig. 4.5.7 It is seen that with increase in (V) cutting speed there is increase in Rvk (Reduced valley height) till 98.09 m/min then it decreases & It is also seen that with increase in (V) cutting speed there is decrease in Rpk (Reduced peak height).**
* **From fig. 4.5.8 it is seen that with increase in (V) cutting speed there is increase in Wx (Maximum depth of waviness) till 98.09 m/min then it decreases.**

### 4.6 Graphical analysis for variable speed at constant feed(0.3mm/rev) and depth of cut(0.30mm)

**4.6.1 45**0rpm feed 0.3mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.6.2 71**0rpm feed 0.3mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.6.3 112**0rpm feed 0.3mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.6.1 Figure 4.6.2**

**Figure 4.6.3 Figure 4.6.4**

**Figure 4.6.5 Figure 4.6.6**

**Figure 4.6.7 Figure 4.6.8**

* **From Fig. 4.6.1 It is seen that with increase in (V) cutting speed there is increase in Ar (Mean spacing of roughness) till 98.09 m/min then it decreases , it is also seen that with increase in (V) cutting speed there is decrease in Rsm (Mean width of profile ).**
* **From fig. 4.6.2 it is seen that with increase in (V) cutting speed there is decrease in both R (Mean depth of roughness) and Ra (Mean roughness parameter ).**
* **From fig. 4.6.3 it is seen that with increase in (V) cutting speed there is decrease in both Rx (Mean depth of profile irregularity) and Pt (Max. peak to valley height).**
* **From fig. 4.6.4 it is seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.6.5 it is seen that with increase in (V) cutting speed there is decrease in Rk (core roughness).**
* **From Fig. 4.6.6 It is seen that with increase in (V) cutting speed there is increase in both MR1 (Material component MR1) and MR2 (Material component MR2) .**
* **From Fig. 4.6.7 It is seen that with increase in (V) cutting speed there is decrease in both Rvk (Reduced valley height) and Rpk (Reduced peak height) till 98.09 m/min then it increases.**
* **From fig. 4.6.8 it is seen that with increase in (V) cutting speed there is decrease in Wx (Maximum depth of waviness).**

### 4.7 Graphical analysis for variable speed at constant feed(0.4mm/rev) and depth of cut(0.2mm)

**4.7.1 45**0rpm feed 0.4mm/rev. D.O.C 0.20mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.7.2 71**0rpm feed 0.4mm/rev. D.O.C 0.20mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.7.3 112**0rpm feed 0.4mm/rev. D.O.C 0.20mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.7.1 Figure 4.7.2**

**Figure 4.7.3 Figure 4.7.4**

**Figure 4.7.5 Figure 4.7.6**

**Figure 4.7.7 Figure 4.7.8**

* **From Fig. 4.7.1 It is seen that with increase in speed there is decrease in Ar (Mean spacing of roughness) till 98.09 m/min then it increases further ,it is also seen that with increase in (V) cutting speed there is decrease in Rsm (Mean width of profile ).**
* **From fig. 4.7.2 it is seen that with increase in (V) cutting speed there is decrease in R (Mean depth of roughness) till 98.09 m/min then it increases ,it is also seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.7.3 it is seen that with increase in (V) cutting speed there is decrease in both Rx (Mean depth of profile irregularity) and Pt (Max. peak to valley height).**
* **From fig. 4.7.4 it is seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.7.5 it is seen that with increase in (V) cutting speed there is decrease in Rk (core roughness).**
* **From Fig. 4.7.6 It is seen that with increase in (V) cutting speed there is decrease in both MR1 (Material component MR1) and MR2 (Material component MR2) till 98.09 m/min then it start increasing with increase in speed.**
* **From Fig.4.7.7 It is seen that with increase in (V) cutting speed there is decrease in both Rvk (Reduced valley height) and Rpk (Reduced peak height) till 98.09 m/min then it start increasing with increase in speed.**
* **From fig.4.7.8 it is seen that with increase in (V) cutting speed there is decrease in Wx (Maximum depth of waviness).**

### 4.8 Graphical analysis for variable speed at constant feed(0.4mm/rev) and depth of cut(0.25mm)

**4.8.1 45**0rpm feed 0.4mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.8.2 71**0rpm feed 0.4mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.8.3 112**0rpm feed 0.4mm/rev. D.O.C 0.25mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.8.1 Figure 4.8.2**

**Figure 4.8.3 Figure 4.8.4**

**Figure 4.8.5 Figure 4.8.6**

**Figure 4.8.7 Figure 4.8.8**

* **From Fig. 4.8.1 It is seen that with increase in speed there is increase in both Ar (Mean spacing of roughness) and Rsm (Mean width of profile ) till 98.09 m/min then it decreases.**
* **From fig. 4.8.2 it is seen that with increase in (V) cutting speed there is decrease in both R (Mean depth of roughness) and Ra (Mean roughness parameter ).**
* **From fig. 4.8.3 it is seen that with increase in (V) cutting speed there is decrease in both Rx (Mean depth of profile irregularity) and Pt (Max. peak to valley height).**
* **From fig. 4.8.4 it is seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.8.5 it is seen that with increase in (V) cutting speed there is decrease in Rk (core roughness).**
* **From Fig. 4.8.6 It is seen that with increase in (V) cutting speed there is increase in both MR1 (Material component MR1) and MR2 (Material component MR2).**
* **From Fig.4.8.7 It is seen that with increase in (V) cutting speed there is decrease in both Rvk (Reduced valley height) and Rpk (Reduced peak height).**
* **From fig.4.7.8 it is seen that with increase in (V) cutting speed there is decrease in Wx (Maximum depth of waviness).**

### 4.9 Graphical analysis for variable speed at constant feed(0.4mm/rev) and depth of cut(0.30mm)

**4.9.1 45**0rpm feed 0.4mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.9.2 71**0rpm feed 0.4mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**4.9.3 112**0rpm feed 0.4mm/rev. D.O.C 0.30mm

### Profile Curve

****

1. **Bearing Area Curve a. R.K.Parameters b. Abbott-Firestone Curve**

****

**3. Roughness And Waviness Motifs (ISO 12085)**

****

**Figure 4.9.1 Figure 4.9.2**

**Figure 4.9.3 Figure 4.9.4**

**Figure 4.9.5 Figure 4.9.6**

**Figure 4.9.7 Figure 4.9.8**

* **From Fig. 4.9.1 It is seen that with increase in speed there is decrease in Ar (Mean spacing of roughness) , it is also seen that with increase in (V) cutting speed there is decrease in Rsm (Mean width of profile ) till 98.09 m/min then it increases.**
* **From fig. 4.9.2 it is seen that with increase in (V) cutting speed there is decrease in R (Mean depth of roughness), till 98.09 m/min then it increases , it is also seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.9.3 it is seen that with increase in (V) cutting speed there is decrease in both Rx (Mean depth of profile irregularity) and Pt (Max. peak to valley height).**
* **From fig. 4.9.4 it is seen that with increase in (V) cutting speed there is decrease in Ra (Mean roughness parameter ).**
* **From fig. 4.9.5 it is seen that with increase in (V) cutting speed there is decrease in Rk (core roughness).**
* **From Fig.4.9.6 It is seen that with increase in (V) cutting speed there is increase in both MR1 (Material component MR1) and MR2 (Material component MR2) till 98.09 m/min then it start decreasing with increase in speed.**
* **From Fig. 4.9.7 It is seen that with increase in (V) cutting speed there is increase in Rvk (Reduced valley height) and with increase in (V) cutting speed there is decrease in Rpk (Reduced peak height) .**
* **From fig. 4.9.8 it is seen that with increase in (V) cutting speed there is decrease in Wx (Maximum depth of waviness).**

**Table 4.2 Machining Data for Ra value.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Diameter**  **(mm)** | **RPM** | **V** | **d** | **Feed** | | **Ra** |
|  | **(m/min)** | **(mm)** | **(m/min)** | **(mm/rev)** | **(µm)** |
| 1. | 44 | 450 | 62.17 | 0.2 | 90 | 0.2 | 3.42 |
| 2. | 44 | 710 | 98.09 | 0.2 | 142 | 0.2 | 2.88 |
| 3. | 44 | 1120 | 154.74 | 0.2 | 224 | 0.2 | 2.59 |
| 4. | 44 | 450 | 62.17 | 0.25 | 90 | 0.2 | 4.12 |
| 5. | 44 | 710 | 98.09 | 0.25 | 142 | 0.2 | 4.09 |
| 6. | 44 | 1120 | 154.74 | 0.25 | 224 | 0.2 | 1.62 |
| 7. | 44 | 450 | 62.17 | 0.3 | 90 | 0.2 | 3.61 |
| 8. | 44 | 710 | 98.09 | 0.3 | 142 | 0.2 | 3.55 |
| 9. | 44 | 1120 | 154.74 | 0.3 | 224 | 0.2 | 2.26 |
| 10. | 44 | 450 | 62.17 | 0.2 | 135 | 0.3 | 4.69 |
| 11. | 44 | 710 | 98.09 | 0.2 | 213 | 0.3 | 3.11 |
| 12. | 44 | 1120 | 154.74 | 0.2 | 336 | 0.3 | 1.62 |
| 13. | 44 | 450 | 62.17 | 0.25 | 135 | 0.3 | 5.03 |
| 14. | 44 | 710 | 98.09 | 0.25 | 213 | 0.3 | 3.33 |
| 15. | 44 | 1120 | 154.74 | 0.25 | 336 | 0.3 | 1.55 |
| 16. | 44 | 450 | 62.17 | 0.3 | 135 | 0.3 | 4.31 |
| 17. | 44 | 710 | 98.09 | 0.3 | 213 | 0.3 | 3.09 |
| 18. | 44 | 1120 | 154.74 | 0.3 | 336 | 0.3 | 1.62 |
| 19. | 44 | 450 | 62.17 | 0.2 | 180 | 0.4 | 4.69 |
| 20. | 44 | 710 | 98.09 | 0.2 | 284 | 0.4 | 2.47 |
| 21. | 44 | 1120 | 154.74 | 0.2 | 448 | 0.4 | 1.93 |
| 22. | 44 | 450 | 62.17 | 0.25 | 180 | 0.4 | 5.1 |
| 23. | 44 | 710 | 98.09 | 0.25 | 284 | 0.4 | 2.89 |
| 24. | 44 | 1120 | 154.74 | 0.25 | 448 | 0.4 | 2.74 |
| 25. | 44 | 450 | 62.17 | 0.3 | 180 | 0.4 | 5.12 |
| 26. | 44 | 710 | 98.09 | 0.3 | 284 | 0.4 | 2.75 |
| 27. | 44 | 1120 | 154.74 | 0.3 | 448 | 0.4 | 2.48 |

**Table 4.3 Machining Data For R.K. parameters.**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.No. | Diameter | V | D.O.C. | Feed | | Ra | Rpk | Rk | Rvk | MR1 | MR2 |
| mm | m/min | mm | m/min | mm/rev |  | µm | µm | µm | (%) | (%) |
| **1** | 44 | 62.17 | 0.2 | 90 | 0.2 | 3.42 | 6.31 | 21.7 | 2.95 | 8.41 | 91.9 |
| **2** | 44 | 98.09 | 0.2 | 142 | 0.2 | 2.88 | 4.31 | 8.74 | 4.26 | 16.2 | 88.6 |
| **3** | 44 | 154.74 | 0.2 | 224 | 0.2 | 2.59 | 0.901 | 6.69 | 5.5 | 5.81 | 79.9 |
| **4** | 44 | 62.17 | 0.25 | 90 | 0.2 | 4.12 | 6.67 | 13.1 | 5.36 | 15.4 | 96.1 |
| **5** | 44 | 98.09 | 0.25 | 142 | 0.2 | 4.09 | 4.06 | 15 | 5.43 | 9.33 | 85.9 |
| **6** | 44 | 154.74 | 0.25 | 224 | 0.2 | 1.62 | 0.806 | 5.87 | 2.92 | 7.29 | 87.8 |
| **7** | 44 | 62.17 | 0.3 | 90 | 0.2 | 3.61 | 4.15 | 14.2 | 3.88 | 9.78 | 93.2 |
| **8** | 44 | 98.09 | 0.3 | 142 | 0.2 | 3.55 | 5.41 | 11.1 | 6.12 | 15.8 | 91.3 |
| **9** | 44 | 154.74 | 0.3 | 224 | 0.2 | 2.26 | 1.1 | 7.79 | 1.57 | 4.1 | 90.2 |
| **10** | 44 | 62.17 | 0.2 | 135 | 0.3 | 4.69 | 6.31 | 21.7 | 2.95 | 8.41 | 91.9 |
| **11** | 44 | 98.09 | 0.2 | 213 | 0.3 | 3.11 | 3.51 | 10.1 | 3.95 | 10 | 84.6 |
| **12** | 44 | 154.74 | 0.2 | 336 | 0.3 | 1.62 | 1.7 | 4.79 | 3.46 | 9.4 | 81.2 |
| **13** | 44 | 62.17 | 0.25 | 135 | 0.3 | 5.03 | 5.47 | 16.7 | 4.87 | 11.5 | 88.8 |
| **14** | 44 | 98.09 | 0.25 | 213 | 0.3 | 3.33 | 4.36 | 11.8 | 6.21 | 10.3 | 94.2 |
| **15** | 44 | 154.74 | 0.25 | 336 | 0.3 | 1.55 | 1.94 | 5.82 | 1.41 | 9.05 | 94.5 |
| **16** | 44 | 62.17 | 0.3 | 135 | 0.3 | 4.31 | 6.35 | 12 | 7.09 | 14.8 | 81.1 |
| **17** | 44 | 98.09 | 0.3 | 213 | 0.3 | 3.09 | 4.96 | 11 | 2.1 | 15.2 | 96.9 |
| **18** | 44 | 154.74 | 0.3 | 336 | 0.3 | 1.62 | 3.28 | 5.05 | 0.663 | 17.6 | 97.2 |
| **19** | 44 | 62.17 | 0.2 | 180 | 0.4 | 4.69 | 7.01 | 15.08 | 3.1 | 20.1 | 97.4 |
| **20** | 44 | 98.09 | 0.2 | 284 | 0.4 | 2.47 | 3.12 | 9.58 | 1.99 | 13.6 | 29.9 |
| **21** | 44 | 154.74 | 0.2 | 448 | 0.4 | 1.93 | 2.88 | 5.52 | 6.77 | 14.9 | 89.1 |
| **22** | 44 | 62.17 | 0.25 | 180 | 0.4 | 5.1 | 7.69 | 16.5 | 5.65 | 20.3 | 90.3 |
| **23** | 44 | 98.09 | 0.25 | 284 | 0.4 | 2.89 | 5.73 | 8.01 | 1.24 | 23.5 | 96.5 |
| **24** | 44 | 154.74 | 0.25 | 448 | 0.4 | 2.74 | 5.2 | 7.54 | 1.21 | 27.7 | 97.1 |
| **25** | 44 | 62.17 | 0.3 | 180 | 0.4 | 5.12 | 8.4 | 17 | 2.29 | 16 | 93 |
| **26** | 44 | 98.09 | 0.3 | 284 | 0.4 | 2.75 | 4.8 | 9.97 | 1.37 | 16.6 | 93.9 |
| **27** | 44 | 154.74 | 0.3 | 448 | 0.4 | 2.48 | 2.46 | 8.43 | 3.3 | 5.45 | 83.9 |

**Table 4.4 Machining Data for Roughness And Waviness Motifs**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.no. | Diameter | V | D.O.C. | Feed |  | R | Rx | Pt | Wx | Ar | Rsm |
|  | mm | m/min | mm | m/min | mm/rev | µm | µm | µm | µm | µm | µm |
| **1** | 44 | 62.17 | 0.2 | 90 | 0.2 | 22.3 | 40.7 | 55.6 | 25.4 | 348 | 85.1 |
| **2** | 44 | 98.09 | 0.2 | 142 | 0.2 | 12 | 20.1 | 31 | 12.7 | 232 | 73.2 |
| **3** | 44 | 154.74 | 0.2 | 224 | 0.2 | 8.94 | 17 | 21.5 | 5.76 | 232 | 79.7 |
| **4** | 44 | 62.17 | 0.25 | 90 | 0.2 | 20.7 | 42.7 | 44.7 | 18.2 | 312 | 116.2 |
| **5** | 44 | 98.09 | 0.25 | 142 | 0.2 | 14.9 | 26 | 34.4 | 14.2 | 188 | 58.6 |
| **6** | 44 | 154.74 | 0.25 | 224 | 0.2 | 5.22 | 11.1 | 12.7 | 3.22 | 216 | 55.5 |
| **7** | 44 | 62.17 | 0.3 | 90 | 0.2 | 16.9 | 28.1 | 44.7 | 21 | 272 | 104.0 |
| **8** | 44 | 98.09 | 0.3 | 142 | 0.2 | 14.5 | 30.2 | 32 | 9.49 | 288 | 61.9 |
| **9** | 44 | 154.74 | 0.3 | 224 | 0.2 | 8.1 | 14.7 | 17.8 | 3.59 | 184 | 49.1 |
| **10** | 44 | 62.17 | 0.2 | 135 | 0.3 | 22.3 | 40.7 | 55.6 | 25.4 | 348 | 85.1 |
| **11** | 44 | 98.09 | 0.2 | 213 | 0.3 | 14.1 | 20.1 | 28.1 | 6.53 | 260 | 69.9 |
| **12** | 44 | 154.74 | 0.2 | 336 | 0.3 | 6.98 | 11.7 | 16.6 | 6 | 232 | 78.4 |
| **13** | 44 | 62.17 | 0.25 | 135 | 0.3 | 20.7 | 42.7 | 44.7 | 18.2 | 312 | 116.2 |
| **14** | 44 | 98.09 | 0.25 | 213 | 0.3 | 12.4 | 30.4 | 52.4 | 19.7 | 216 | 121.4 |
| **15** | 44 | 154.74 | 0.25 | 336 | 0.3 | 6.08 | 15 | 16.6 | 9.15 | 200 | 82.7 |
| **16** | 44 | 62.17 | 0.3 | 135 | 0.3 | 15.7 | 37.7 | 48.8 | 18.4 | 256 | 97.0 |
| **17** | 44 | 98.09 | 0.3 | 213 | 0.3 | 12.4 | 18.8 | 24.1 | 10.1 | 260 | 82.0 |
| **18** | 44 | 154.74 | 0.3 | 336 | 0.3 | 6.32 | 12.6 | 15.3 | 7.79 | 224 | 78.6 |
| **19** | 44 | 62.17 | 0.2 | 180 | 0.4 | 21.2 | 35.2 | 48.5 | 27.9 | 372 | 108.7 |
| **20** | 44 | 98.09 | 0.2 | 284 | 0.4 | 10.1 | 18.1 | 25.8 | 8.42 | 256 | 71.7 |
| **21** | 44 | 154.74 | 0.2 | 448 | 0.4 | 12.6 | 16.9 | 17.6 | 2.44 | 328 | 53.2 |
| **22** | 44 | 62.17 | 0.25 | 180 | 0.4 | 19.1 | 38.2 | 52.5 | 25.3 | 280 | 103.5 |
| **23** | 44 | 98.09 | 0.25 | 284 | 0.4 | 11.6 | 20.9 | 24.6 | 9.81 | 324 | 120.1 |
| **24** | 44 | 154.74 | 0.25 | 448 | 0.4 | 10.3 | 15.7 | 18.7 | 0 | 316 | 114.0 |
| **25** | 44 | 62.17 | 0.3 | 180 | 0.4 | 22.3 | 34.7 | 36.9 | 11.9 | 344 | 114.0 |
| **26** | 44 | 98.09 | 0.3 | 284 | 0.4 | 9.54 | 19.5 | 22.5 | 7.55 | 244 | 107.0 |
| **27** | 44 | 154.74 | 0.3 | 448 | 0.4 | 9.92 | 15.3 | 20.2 | 7.11 | 228 | 801.0 |

**Chapter 5**

**RESULTS AND CONCLUSION**

A systematic approach was used to reduce the cost and time of experiment and analyse the mean effect of the data collected from result graphs.

1. **Profile Curve gives**

* **Ra (Mean roughness parameter )** 
  + - * Ra decrease with increase in cutting speed.
      * Ra increase up to 0.25mm and then decrease with increase in depth of cut.
      * Ra increase with increase in feed.

**2. Bearing Area Curve for R.K. Parameters and Abbott-Firestone Curve**

* **Rk (Depth of the roughness core profile)**
  + - * Rk decrease with increase in cutting speed.
      * Rk decrease with increase in depth of cut.
      * Rk decrease with increase in feed.
* **MR1(Upper limit of the core roughness)**
  + - * MR1 increase up to 98.09 m/min and then decrease with increase in cutting speed.
      * MR1 increase up to 0.25mm and then decrease with increase in depth of cut.
      * MR1 Increase with increase in feed.
* **MR2 (Lowest limit of the core roughness)**
  + - * MR2 decrease up to 98.09 m/min and then increase with increase in cutting speed.
      * MR2 increase up to 0.25mm and then decrease with increase in depth of cut.
      * MR2 increase up to 0.30mm/rev. and then decrease with increase in feed.
* **Rpk (Top portion of the surface to be worn away)**
  + - * Rpk decrease with increase in cutting speed.
      * Rpk increase up to 0.25mm and then decrease with increase in depth of cut.
      * Rpk Increase with increase in feed.
* **Rvk (Lowest part of the surface retaining the lubricant)**
  + - * Rvk decrease with increase in cutting speed.
      * Rvk increase up to 0.25mm and then decrease with increase in depth of cut.
      * Rvk Increase with increase in feed.

1. **Roughness And Waviness Motifs (ISO 12085)**

* **R (Average depth of roughness motifs)**
* R decrease with increase in cutting speed
* R decrease with increase in depth of cut.
* R decrease up to 0.30mm/rev. and then increase with increase in feed.
* **Ar (Average spacing of roughness motifs)**
* Ar decrease with increase in cutting speed.
* Ar decrease with increase in depth of cut.
* Ar increase with increase in feed.
* **Rsm (Average spacing of waviness motifs)**
* Rsm decrease with increase in cutting speed.
* Rsm increase up to 0.25mm and then decrease with increase in depth of cut.
* Rsm increase with increase in feed.
* **Rx (Maximum depth of roughness motifs)**
* Rx decrease with increase in cutting speed.
* Rx increase up to 0.25mm and then decrease with increase in depth of cut.
* Rx decrease with increase in feed.
* **Pt (Maximum depth of the raw profile)**
* Pt decrease with increase in cutting speed.
* Pt increase up to 0.25mm and then decrease with increase in depth of cut.
* Pt increase up to 0.30mm/rev. and then decrease with increase in feed.
* **Wx (Maximum depth of waviness motifs)**
* Wx decrease with increase in cutting speed.
* Wx decrease with increase in depth of cut.
* Wx increase up to 0.30mm/rev. and then decrease with increase in feed.

5.1 **Scope for future work**

The machining variables are divided into three main categories. These are tool variables, work piece variables and set-up variables. Tool variables includes tool material, nose radius, tool wear, tool geometry, tool vibration, machine tool rigidity, and tool overhang etc. Work piece variables include work piece material, hardness, length and diameter etc. Set-up variables include cutting speed, feed rate, depth of cut etc. In the present work only set-up variables are considered. Tool variables and work piece variables can also be studied. There is also scope for considering more factors levels, interactions to optimize a selected set of parameters.

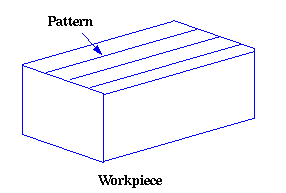
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**1. Surface Roughness Terminology:**

The quality of machined surface is characterized by the accuracy of its manufacture with respect to the dimensions specified by the designer. Every machining operation leaves characteristic evidence on the machined surface. This evidence in the form of finely spaced micro irregularities left by the cutting tool. Each type of cutting tool leaves its own individual pattern which therefore can be identified. This pattern is known as surface finish or surface roughness.



**2. Roughness:**

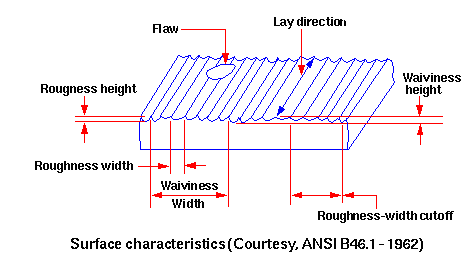
Roughness consists of surface irregularities which result from the various machining process. These irregularities combine to form surface texture.

### 3. Roughness Height:

It is the height of the irregularities with respect to a reference line. It is measured in millimeters or microns or micro inches. It is also known as the height of unevenness.

### 4. Roughness Width:

The roughness width is the distance parallel to the nominal surface between successive peaks or ridges which constitute the predominate pattern of the roughness. It is measured in millimeters.



**5. Roughness Width Cut Off:**

Roughness width cut off is the greatest spacing of respective surface irregularities to be included in the measurement of the average roughness height. It should always be greater than the roughness width in order to obtain the total roughness height rating.

**6. Lay:**

Lay represents the direction of predominant surface pattern produced and it reflects the machining operation used to produce it.

**7. Waviness:**

This refers to the irregularities which are outside the roughness width cut off values. Waviness is the widely spaced component of the surface texture. This may be the result of work piece or tool deflection during machining, vibrations or tool run out.

**8. Waviness Width:**

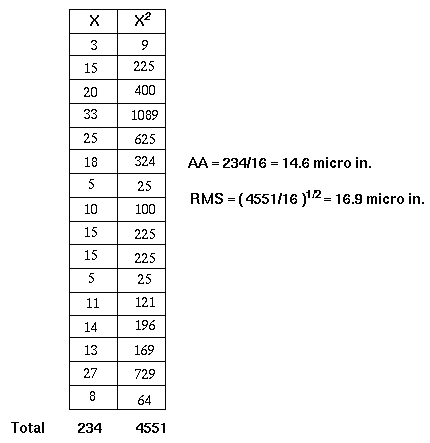
Waviness height is the peak to valley distance of the surface profile, measured in millimeters.

**9. Arithmetic Average (AA):**

A close approximation of the arithmetic average roughness-height can be calculated from the profile chart of the surface. Averaging from a mean centerline may also be automatically performed by electronic instruments using appropriate circuitry through a meter or chart recorder. If X is the measured value from the profilometer, then the AA value can be calculated as shown below.

**10. Root Mean Square (rms):**

The rms value can be calculated as shown below. Its numerical value is about 11% higher than that of AA.



**11. Cut-off value**

The cut-off value controls the measurement length. For example, if an 0.8mm cut-off is selected and 7 sample lengths are measured, then the measurement length will be 7 x 0.8=5.6mm. In general for good statistical analysis, it is recommended that 5 sample lengths be used for assessment, although this is not always possible. If a 2CR filter is used, then 2 cut-offs will be discarded. This means the measurement length for a 2CR type filter will have to be 7 x 0.8 to allow for the 2 discarded cut-offs leaving a final 5 sample lengths for assessment. The Gaussian type filter is different and only discards one sample length.

**13. Stylus Tip Radius**

The stylus tip radius is a key feature that is often overlooked. Assuming that a conisphere stylus is being used, the profile recorded by the instrument will in effect be the locus of the centre of a ball, whose radius is equal to that of the stylus tip, as it is rolled over the surface. This action broadens the peaks of the profile and narrows the valleys. For simplicity, if we consider the surface to be a sine wave, then this distortion is dependent both on the wavelength and the amplitude.