

Literature Review on Optimization of Surface Roughness during Turning Operation

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ABSTRACT: The mechanical manufacturing industries are regularly challenged for achieving higher productivity and high quality products in order to remain competitive. The desired shape, size and finished ferrous and non ferrous materials are conventionally produced through turning the preformed blanks with the help of cutting tools that moved past the work piece in a machine tool. Among various cutting processes, turning process is one of the most fundamental and most applied metal removal operations in a real manufacturing environment. The surface roughness of the machined parts is one of the most significant product quality characteristic which refers to the deviation from the nominal surface. Surface roughness plays a vital role in many applications such as precision fits, fastener holes, aesthetic requirements and parts subject to fatigue loads. Surface roughness imposes one of the most significant constraints for the selection of cutting parameters and machine tools in development of a process. Surface finish in turning has been found to be influenced in varying amounts by a number of factors such as feed rate, work material characteristics, work hardness, unstable built-up edge, cutting speed, depth of cut, cutting time, tool nose radius and tool cutting edge angles, stability of machine tool and work piece setup, chatter, and use of cutting fluids.

KEYWORDS: Productivity, Surface Roughness, Turning, Cutting Parameters

I. INTRODUCTION

TURNING OPERATION Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters.

Turning is the machining operation (Fig.1) that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface:

- With the work piece rotating.
- With a single-point cutting tool, and
- With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work.

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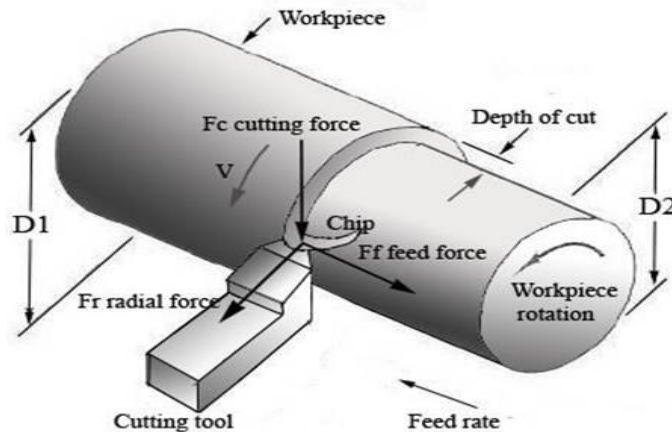


Fig. 1: Process of Turning Operation

Taper turning is practically the same, except that the cutter path is at an angle to the work axis. Similarly, in contour turning, the distance of the cutter from the work axis is varied to produce the desired shape. Even though a single-point tool is specified, this does not exclude multiple-tool setups, which are often employed in turning. In such setups, each tool operates independently as a single-point cutter.

ADJUSTABLE CUTTING FACTORS IN TURNING

The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as kind of material and type of tool have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine.

Speed:

Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute (rpm) it tells their rotating speed. But the important feature for a particular turning operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the circumference of the work piece before the cut is started. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same.

$$V = 3.14 * D * N / 1000 \text{ m/min}$$

Here, v is the cutting speed in turning, D is the initial diameter of the work piece in mm, and N is the spindle speed in RPM.

Feed: Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev.

$$F = f * N \text{ mm/min}$$

Here, $m F$ is the feed in mm per minute, f is the feed in mm/rev and N is the spindle speed in RPM.

Depth of Cut: Depth of cut is practically self explanatory. It is the thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm. It is

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important to note, though, that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.

$$d = (D - d)/2 \text{ mm}$$

Here, D and d represent initial and final diameter (in mm) of the job respectively.

SURFACE INTEGRITY

Surface integrity is the sum of all the elements that describes all the conditions existing on or at the surface of a work piece. Surface integrity has two aspects. The first is surface topography which describes the roughness, 'lay' or texture of this outermost layer of the work piece, i.e., its interface with the environment. The second is surface metallurgy which describes the nature of the altered layers below the surface with respect to the base of the matrix material. This term assesses the effect of manufacturing processes on the properties of the work piece material.

Surface integrity describes not only the topological (geometric) features of surfaces and their physical and chemical properties, but their mechanical and metallurgical properties and characteristics as well. Surface integrity is an important consideration in manufacturing operations because it influences properties, such as fatigue strength, resistance to corrosion, and service life.

SURFACE TOPOGRAPHY

Outermost layers of all machined surfaces display a great number of both macro geometrical and micro-geometrical deviations from the ideal geometrical surface. Surface roughness refers to deviation from the nominal surface of the third up to sixth order.

Order of deviation is defined in international standards. First and second-order deviations refer to form, i.e. flatness, circularity, etc. and to waviness, respectively, and are due to machine tool errors, deformation of the work piece, erroneous setups and clamping, vibration and work piece material inhomogenities. Third and fourth-order deviations refer to periodic grooves, and to cracks and dilapidations, which are connected to the shape and condition of the cutting edges, chip formation and process kinematics. Fifth and sixth-order deviations refer to work piece material structure, which is connected to physical-chemical mechanisms acting on a grain and lattice scale (slip, diffusion, oxidation, residual stress, etc.). Different order deviations are superimposed and form the surface roughness profile (Fig. 2).

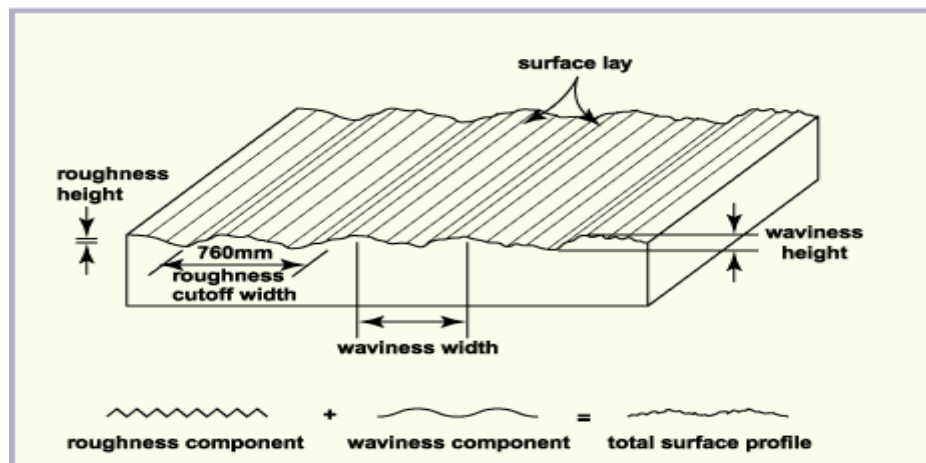


Fig. 2: Surface Roughness

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FACTORS AFFECTING THE SURFACE FINISH

Whenever two machined surfaces come in contact with one another the quality of the mating parts plays an important role in the performance and wear of the mating parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as:

- A) The machining variables which include
 - a) Cutting speed
 - b) Feed, and
 - c) Depth of cut.
- B) The tool geometry
Some geometric factors which affect achieved surface finish include:
 - a) Nose radius b) Rake angle c) Side cutting edge angle, and d) Cutting edge.
- C) Work piece and tool material combination and their mechanical properties
- D) Quality and type of the machine tool used,
- E) Auxiliary tooling, and lubricant used, and
- F) Vibrations between the work piece, machine tool and cutting tool.

II. LITERATURE SURVEY

This heading entails a detailed review of literature on the effect of various cutting parameters on surface roughness during turning process of hard to machine materials.

The literature review includes the research carried out on alloy steel, and other hard to machine materials, effect of coolant while machining of hard to machine materials.

Surface roughness is a factor that greatly influences manufacturing cost. It describes the geometry of the machined surfaces and combined with the surface texture. To select the cutting parameters properly, several mathematical models based on neural network or statistical regression techniques have been constructed to establish the relationship between the cutting performance and cutting parameters.

The literatures reviewed on surface integrity, Taguchi concepts and Grey analysis are as follows:

A. SURFACE INTEGRITY

Abdallah A. et al., [1] recognized the importance of achieving dimensional accuracy, good surface finish and maximum material removal rate in the machining process; and optimized the cutting parameters viz. Feed, cutting speed and depth of cut for maximizing the surface finish and material removal rate for an aluminum alloy 6061. L-9 orthogonal array, signal- to-noise ratio, analysis of variation has been employed to study the process characteristics, and Taguchi method experiment design has been used to optimize the cutting parameters for the material using uncoated inserts. An experiment has been conducted to confirm and verify the effectiveness of Taguchi optimization method. Surface roughness and material removal rate are found to be maximum at 11.6% and 14%; and minimum at 4.4% and 3.7% respectively. Cutting parameters viz. cutting speed, feed rate and depth of cut are found to be affecting the machining process at 45%, 36% and 19% respectively for minimum surface finish of 0.256 microns with an error percentage of 4.4%

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Abhang L.B. and Hameedullah M., [2] carried out the experimental work to optimize the cutting parameters viz. feed rate, depth of cut and lubricant temperature in the turning operation of EN-31 steel alloy by using tungsten carbide inserts. The work aimed at explaining and demonstrating the systematic procedure of Taguchi parameter design; finding the optimal combination of cutting parameters using the signal-to-noise ratio; knowing the significance level of each cutting parameter using ANOVA analysis; and therefore finding out the effect of lubricating temperature on the response i.e. surface finish. It has been proved experimentally that better surface finish can be observed with cooled lubricant and higher depth of cuts.

Paul B. K. M. et al., [3] experimentally investigated, and optimized the effect of cutting speed, feed and depth of cut on the surface finish, tool wear and cutting force in a continuous dry turning of hardened alloy steel, AISI 4340 having hardness: 48(48-52) HRC using the Taguchi design of experiments. It was observed that for tool wear feed has significant influence and depth of cut is the least influential of all. Optimal conditions are obtained at cutting speed (140 m/min), feed (0.125mm/rev), and depth of cut (0.8mm).

Choudhary I.A. et al. [4] discusses the development of surface roughness prediction models for turning EN 24T steel (290 BHN) utilizing response surface methodology. A factorial design technique was used to study the effects of the main cutting parameters such as cutting speed, feed and depth of cut, on surface roughness. The tests were carried out using uncoated carbide inserts without any cutting fluid. They reveals 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 effects of cutting variables on responses such as surface roughness and tool life.

Asilturk Ilhan et al. [5] focus on optimizing turning parameters based on Taguchi method to minimize surface roughness (R_a and R_z). Experiments have been conducted using L9 orthogonal array in a CNC turning machine. Dry turning tests were carried out on hardened AISI 4140 (51 HRC) with coated carbide cutting tools. As a result they observed that the feed rate has the most significant effect on R_a and R_z .

Davim J. Paulo et al. [6] developed surface roughness prediction models using artificial neural network (ANN) to investigate the effects of cutting conditions during turning of free machining steel, 9SMnPb28k(DIN). The ANN model of surface roughness parameters (R_a and R_t) were developed with the cutting conditions such as feed rate, cutting speed and depth of cut as the affecting process parameters. The experiments were planned as per L27 orthogonal array with three levels defined for each of the factors in order to develop the knowledge base for ANN training using error back propagation training algorithm (EBPTA). 3D surface plots were generated using ANN model to study the interaction effects of cutting conditions on surface roughness 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. The details of experimentation, ANN training and validation are presented in the paper

Rech J. et al. [7] reveals that the process effects on significant engineering properties of work materials have to be carefully analyzed. Roughness, residual stresses, and white layers as parts of surface integrity, are functions of the machining parameters and of the cut ability of the cutting edge, i.e. of the tool wear. The aim of this work was to study the influence of feed rate, cutting speed, and tool wear on the effects induced by hard turning on case-hardened 27MnCr5 gear cone brakes and to point out the technical limitations in mass production.

Sharman A.R.C. et al. [8] analyze surface integrity data from a full factorial experiment was presented when turning Ti-45Al-2Mn-2Nb+0.8 vol. % TiB₂ employing extremely fine finishing cuts. Workpiece surfaces/sub-surfaces were evaluated in relation to micro-structural alterations, strain hardening/microhardness changes, and 2D surface roughness (R_a). All the machined surfaces contained cracks, cracked TiB₂ particles, deformed microstructure and microhardness increases regardless of the operating parameters. However, when comparing the surfaces with those obtained in previous work using more abusive parameters, a significant reduction in surface damage was obtained.

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Nalbant M. et al [9] apply 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. Experimental results are provided to illustrate the effectiveness of this approach.

Ahmed [10] developed the methodology required for obtaining optimal process parameters for prediction of surface roughness in Al turning. For development of empirical model nonlinear regression analysis with logarithmic data transformation was applied. The developed model showed small errors and satisfactory results. The study concluded that low feed rate was good to produce reduced surface roughness and also the high speed could produce high surface quality within the experimental domain.

Abburi and Dixit [11] developed a knowledge-based system for the prediction of surface roughness in turning process. Fuzzy set theory and neural networks were utilized for this purpose. The authors developed rule for predicting the surface roughness for given process variables as well as for the prediction of process variables for a given surface roughness.

Al-Ahmari [12] developed empirical models for tool life, surface roughness and cutting force for turning operation. The process parameters used in the study were speed, feed, depth of cut and nose radius to develop the machinability model. The methods used for developing aforesaid models were Response Surface Methodology (RSM) and neural networks (NN).

Doniavi et al. [13] used response surface methodology (RSM) in order to develop empirical model for the prediction of surface roughness by deciding the optimum cutting condition in turning. The authors showed that the feed rate influenced surface roughness remarkably. With increase in feed rate surface roughness was found to be increased. With increase in cutting speed the surface roughness decreased. The analysis of variance was applied which showed that the influence of feed and speed were more in surface roughness than depth of cut.

Feng and Wang [14] investigated for the prediction of surface roughness in finish turning operation by developing an empirical model through considering working parameters: work piece hardness (material), feed, cutting tool point angle, depth of cut, spindle speed, and cutting time. Data mining techniques, nonlinear regression analysis with logarithmic data transformation were employed for developing the empirical model to predict the surface roughness.

Fnides et al. [15] studied on machining of slide-lathing grade X38CrMoV5-1 steel treated at 50 HRC by a mixed ceramic tool (insert CC650) to reveal the influences of cutting parameters: feed rate, cutting speed, depth of cut and flank wear on cutting forces as well as on surface roughness. The authors found that tangential cutting force was very sensitive to the variation of cutting depth. It was observed that surface roughness was very sensitive to the variation of feed rate and that flank wear had a great influence on the evolution of cutting force components and on the criteria of surface roughness.

Fu and Hope [16] established an intelligent tool condition monitoring system by applying a unique fuzzy neural hybrid pattern recognition system. The study concluded that armed with the advanced pattern recognition methodology, the established intelligent tool condition monitoring system had the advantages of being suitable for different machining conditions, robust to noise and tolerant to faults.

Kirby et al. [17] developed the prediction model for surface roughness in turning operation. The regression model was developed by a single cutting parameter and vibrations along three axes were chosen for in-process surface roughness prediction system. By using multiple regression and Analysis of Variance (ANOVA) a strong linear relationship among the parameters (feed rate and vibration measured in three axes) and the response (surface roughness) was found. The

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authors demonstrated that spindle speed and depth of cut might not necessarily have to be fixed for an effective surface roughness prediction model.

Kohli and Dixit [18] proposed a neural-network-based methodology with the acceleration of the radial vibration of the tool holder as feedback. For the surface roughness prediction in turning process the back-propagation algorithm was used for training the network model. The methodology was validated for dry and wet turning of steel using high speed steel and carbide tool and observed that the proposed methodology was able to make accurate prediction of surface roughness by utilizing small sized training and testing datasets.

III. CONCLUSION

A lot of work has been done in finding out optimum values of cutting parameters which provide best surface finish while turning of hard materials but still there are various materials on which the same work has not been performed. So, as per literature it has been found that there is very less work has been done on optimization of cutting parameters for surface roughness for alloy steel series.

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