Analysis of Surface Roughness with Different Cutting Parameters in Turning: A Review

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Abstract— This paper is all about the steps and procedures used to optimize turning parameters using Taguchi's design of experiment. An attempt is made to review the literature on optimizing machining parameters in turning processes. In this study, analysis will be done by process parameter like cutting speed, feed rate and depth of cut based on surface roughness in finish turning of work piece material with carbide tool having different rack angle. The surface roughness will measure at the end of useful tool life. The combine effects of the process parameters on performance characteristics will investigating using ANOVA and will normality testing optimization technique will help to optimize the process parameters.
Key words: Turning, MRR, SR, ANOVA, Taguchi

I. Working Principle of Turning

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

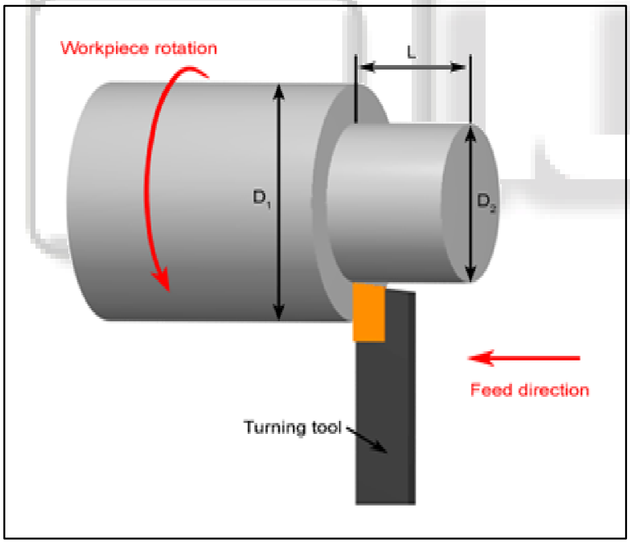

Fig. 1: Turning Process

1) With the work piece rotating,
2) With a single-point cutting tool,
3) 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.

A. *Cutting Conditions for 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.

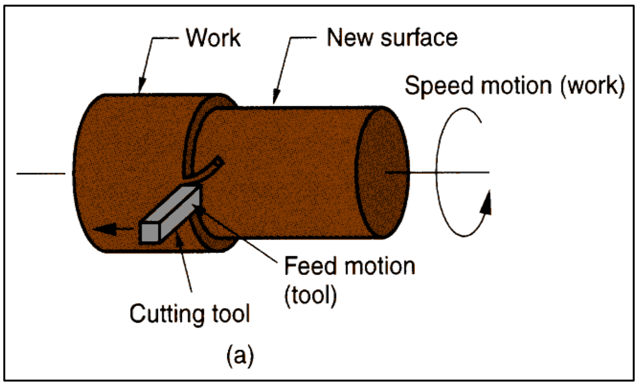

Fig. 2: Cutting Process in Turning

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 figure 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 (in feet) of the work piece before the cut is started. It is expressed in surface feet per minute (s fpm), 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.

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 inches (of tool advance) per revolution (of the spindle), or ipr. The figure, by the way, is usually much less than an inch and is shown as decimal amount.

Depth of Cut is practically self-explanatory. It is the thickness of the layer being removed from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in inches. It is 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.

B. *Factors Influencing Cutting Process*

Parameter	Influence and Interrelationship
Cutting speed depth of cut, feed, and cutting fluids.	Forces power, temperature rise, tool life, type of chips, surface finish.
Tool angles	As above; influence on chip flow direction; resistance to tool chipping.
Continuous chip	Good surface finish, steady cutting forces, undesirable in automated machinery.
Built-up-edge chip	Poor surface finish, thin stable edge can product tool surface.

Discontinuous chip	Desirable for ease of chip disposal, fluctuating cutting forces can affect surface finish and cause vibration and chatters.
Temperature rise	Influences surface finish, dimensional accuracy, temperature rise, forces and power.
Tool wear	Influences surface finish, dimensional accuracy, temperature rise, forces and power.
Machinability	Related to tool life, surface finish, forces and power

Table 1: Factors Influencing Cutting Process

C. Tool Geometry

- **Shank:** Main body of tool, it is part of tool which is gripped in tool holder.
- **Face:** Top surface of tool b/w shank and point of tool. Chips flow along this surface.
- **Flank:** Portion tool which faces the work. It is surface adjacent to & below the cutting edge when tool lies in a horizontal position.

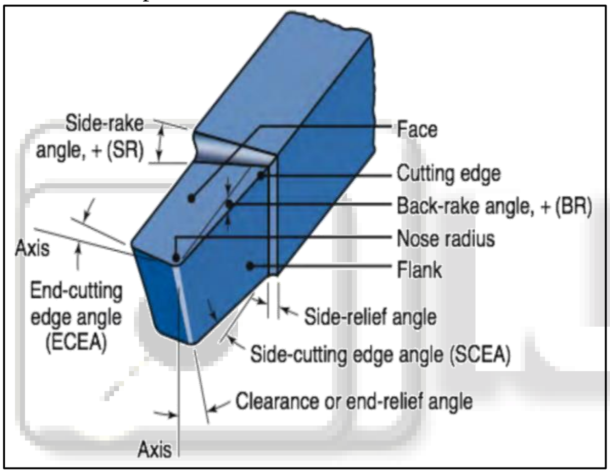

Fig. 3: Tool Geometry

- **Point:** Wedge shaped portion where face & flank of tool meet.
- **Base:** Bearing surface of tool on which it is held in a tool holder.
- **Nose radius:** Cutting tip, which carries a sharp cutting point. Nose provided with radius to enable greater strength, increase tool life & surface life.
- Typical Value: 0.4 mm – 1.6 mm

D. Rack Angle

Rake angle is a parameter used in various cutting and machining processes, describing the angle of the cutting face relative to the work. There are two rake angles, namely the back rake angle and side rake angle, both of which help to guide chip flow.

There are three types of rake angles: *positive*, *negative*, and *zero*.

- **Positive Rake Angles:** Make the tool sharper and pointed. This reduces the strength of the tool, as the small included angle in the tip may cause it to chip away. Reduce cutting forces and power requirements. Helps in the formation of continuous chips in ductile materials. Can help avoid the formation of a built-up edge.
- **Negative Rake Angles:** Make the tool more blunt, increasing the strength of the cutting edge. Increase the cutting forces. Can increase friction, resulting in higher temperatures. Can improve surface finish.
- **Zero Rake Angle** is the easiest to manufacture, but has a larger crater wear when compared to positive rake angle as the chip slides over the rake face. Recommended rake angles can vary depending on the material being cut, tool material, depth of cut, cutting speed, machine, and setup. This table summarizes recommended rake angles for single-point turning on a lathe; rake angles for drilling, milling, or sawing are often different.

II. LITERATURE REVIEW

Robert, et. al. [1] had investigated Formation of the segments during the turning of hardened steel causes their elongation and decreasing the chip thickness. The result is formation of thin long chips, the chip ratio is smaller than 1, in comparison with the turning of annealed steel (thick and continuous chip, with the chip ratio higher than 1). The length of segments and the segmentation frequency increase with cutting speed. This process of the chip formation significantly affects all parameters related to the plastic deformation in the cutting zone. Moreover, the formation of the segmented chip causes instability of a cutting process, the high intensity of tool wear and generation of significant heat in the cutting zone. The chip thickness during turning of hardened steel 100Cr6 is much lower than for turning of annealed one. Formation of the segments during the turning of the hardened steel causes their elongation and decreasing of the chip thickness.

Hamdi Aouici, et. al. [2] had studied The effects of cutting speed, feed rate, work piece hardness and depth of cut on surface roughness and cutting force components in the hard turning with AISI H11 steel using cubic boron nitride (CBN 7020 from Sandvik Company) which is essentially made of 57% CBN and 35% TiCN.Four-factor (cutting speed, feed rate, hardness and depth of cut) and three-level fractional experiment designs completed with a statistical analysis of variance (ANOVA) were performed. Mathematical models for surface roughness and cutting force components were developed using the response surface methodology (RSM). This research seems that the best surface roughness was achieved at the lower feed rate and the highest cutting speed. The effects of two-factor interactions feed rate and depth of cut, cutting speed and work piece hardness, cutting speed and feed rate, work piece hardness and feed rate, and the products (H2 and ap2) appeared also to be important. The feed force (Fa) and the cutting force (Fv) are strongly influenced by the depth of cut, (56.77%) and (31.50%) respectively. On the opposite, the cutting speed has a very small influence (0.14%).

Harsh Valera et. al. [3] had studied power consumption and roughness characteristics of surface generated in turning operation of EN-31 alloy steel with TiN+Al2O3+TiCN coated tungsten carbide tool under different cutting parameters. The study showed the influences of three cutting parameters like spindle speed, depth of cut, feed rate affecting surface roughness as well as power consumption while turning operation of EN-31 alloy steel. Total 15 experiments were carried out with by varying different spindle speed, keeping feed rate 0.08 mm/rev and depth of cut 0.4 mm. The experimental setup as shown in table 1.

Test No.	Spindle speed, rpm	Feed, mm/rev	Depth of cut, Mm	Surface roughness, µm	Power consumption, watt
1	112	0.08	0.4	3.58	15
2	280	0.08	0.4	3.4	30
3	450	0.08	0.4	1.45	105
4	710	0.08	0.4	1.5	120
5	1120	0.08	0.4	1.15	210
6	710	0.045	0.4	0.78	90
7	710	0.071	0.4	0.84	150
8	710	0.08	0.4	1.09	180
9	710	0.1	0.4	1.03	120
10	710	0.125	0.4	1.39	210
11	710	0.08	0.4	1.35	210
12	710	0.08	0.6	1.49	295
13	710	0.08	0.8	1.23	345
14	710	0.08	1.0	1.67	390
15	710	0.08	1.2	2.02	495

Table 1: Cutting condition and response [3]

It can be concluded that spindle speed, feed, and depth of cut significantly affect the surface roughness and power consumption while turning EN31 alloy steel using coated carbide cutting tool. To optimize the cutting parameters for achieving better surface finish with reduced power consumption detailed DOE is needed for the work piece material.

Esmaeil Soltani, et. al. [4] attempt has been made to model and optimize hard turning AISI D3 hardened steel using response surface methodology effects of four machining parameters, including cutting speed, feed rate, hardness and tool corner radius were investigated based on two performance characteristics involving surface roughness and main cutting force. He used Central composite design (CCD) as an experimental design and Al2O3/TiC mixed ceramic tool with three different corner radius including 0.4, 0.8 and 1.2 were employed to accomplish 30 tests with six center points. This investigation results that Sequential approximation optimization method was applied to obtain optimal condition of machining factor. In this way, 184.34m/min for cutting speed, 0.05mm/rev for feed rate, 49HRc for work piece hardness and 1.2mm for tool corner radius were proposed as optimal levels of machining parameters in order to minimize surface roughness and main cutting force. Under the optimal condition, surface roughness and main cutting force increased 15% and 21% respectively in comparison with initial condition.

Suleiman Abdulkareem, et. al. [5] done the experimental investigation of the influence of the three most important machining parameters of depth of cut, feed rate and spindle speed on surface roughness during turning of mild steel and used Box Behnken experimental design method as well as analysis of variance (ANOVA) to analyze the influence of machining parameters on surface roughness height Ra using multiple linear regressions. Confirmation results were used to confirm that mathematical models are good enough to effectively represent machining criteria of surface roughness Ra during the study. He concludes on the basis of experiment that he feed rate is found to be the most important parameter effecting ra, followed by cutting speed while spindle speed has the least effect and machining with high cutting speed and spindle speed has positive effect on Ra as against feed rate. The predicted value of Ra matches the experimental values reasonably well, with high value of coefficient of determination (R2 = 0.99) for Ra. The variation in percentage error for R is between 1 to5%, which shows that the model developed for Ra is accurate, and can be used for predicting the surface roughness.

Sudhansu Ranjan Das, et. al. [6] investigated the effect of machining parameters such as cutting speed, feed and depth of cut on surface roughness during dry turning of hardened aisi 4340 steel using coated carbide inserts. Turning of hardened steels using a single point cutting tool has replaced the cylindrical grinding now as it offers attractive benefits in terms of lower equipment costs, shorter set up time, fewer process setups, higher material removal rate, better surface quality and elimination of cutting fluids compared to cylindrical grinding. A full factorial design of experiment is selected for experimental planning and the analysis of variance (ANOVA) has been employed to analyze the significant machining parameters on surface roughness during turning. In the result they observed from the ANOVA that feed (60.85%) is the most significant parameter followed by cutting speed (24.6%) and the two level interactions were significant between cutting speed, feed (6.23%) and depth of cut-feed (2.62%) on surface roughness. From the experimentation it is found that, depth of cut did not impact the surface roughness in the studied range, significantly. The most optimal results for surface roughness were observed when cutting speed was set at 150 m/min and feed of 0.05 mm/rev. The present research work on turning of hardened AISI 4340 steel with CVD multilayer coated carbide insert will be useful for the advanced engineering industries those are working in the field of precision machining.

N Ganesh, et al. [7] In this task of Turning it is focused to find optimum cutting parameters such as Spindle speed, Feed and Depth of cut in order to have improved performance on Machining time and Surface Roughness. This work focuses on CNC turning of EN 8 steel using Cemented Carbide tool for varying Spindle speed, Feed and Depth of cut. The experiment is designed for Second order linear model using Response Surface Method (CCD). Mathematical formulation is carried out by correlating the values of responses Machining time and Surface Roughness with the contribution of Spindle speed, Feed and Depth to develop the Empirical models for the responses.

Subhajit Dangar, et al. [8] In the study the control parameters of a cast iron specimen undergoing turning operation are optimized so as to obtain minimum surface roughness. The parameters most responsible for surface roughness are identified and their working ranges are set. These parameters are spindle speed, feed rate and depth of cut. Experiments are conducted using parameter combinations obtained by Taguchi's L-9 orthogonal array and corresponding surface roughness are noted. S/N ratio calculations are done to find the significance order of the control parameters. Next analysis of variance (ANOVA) verifies the working ranges of the control parameters and their order of significance.

Ashvin J. Makadia et al. [9] Design of experiments has been used to study the effect of the main turning parameters such as feed rate, tool nose radius, cutting speed and depth of cut on the surface roughness of AISI 410 steel. A mathematical prediction model of the surface roughness has been developed in terms of above parameters. The effect of these parameters on the surface roughness has been investigated by using Response Surface Methodology (RSM). Response surface contours were constructed for determining the optimum conditions for a required surface roughness. The developed prediction equation shows that the feed rate is the main factor followed by tool nose radius influences the surface roughness. The surface roughness was found to increase with the increase in the feed and it decreased with increase in the tool nose radius. The verification experiment is carried out to check the validity of the developed model that predicted surface roughness within 6% error.

Daymi, et. al. [10] researched to make a first experimental analysis of the effect of the cutting speed on the chip morphology, and of the cutting forces in the orthogonal turning process of the titanium alloys Ti-6Al-4V.

III. Conclusions

A. *Surface Finish*

- **Speed:** We get good surface finish when increase speed.
- **Feed:** When feed rate is increase then surface finish quality is decrease.
- **Depth of cut:** When depth of cut is increase, surface finish is decrease.
- Surface finish is more significant on combination of cutting speed and feed rate

B. *Temperature*

- **Speed:** When speed is increase, temperature is increase.
- **Feed:** When feed rate is increase, temperature is increase.
- **Depth of cut:** When depth of cut is increase, temperature is increase.
- Temperature is more significant on combination of cutting speed and feed rate.

C. *Tool Flank Wear*

- **Speed:** Moderate cutting speed should be preferred for minimum tool flank wear.
- **Feed:** At lower feed rate tool flank wear is decrease.
- **Depth of cut:** Lower depth of is preferable for minimum tool wear.
- Tool flank wear is more significant on the combination of feed and depth of cut.

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