JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

OPTIMIZATION OF CUTTING PARAMETERS IN TURNING OPERATION BY USING TAGUCHI METHOD

DAGGUPATI MADHU
P.G. Scholar
Sri Venkateswara Institute
of Technology,
Ananthapuram,
Andhra Pradesh, India.

Mr. N. PHANI RAJA RAO
Asst. Prof & HOD
Sri Venkateswara Institute
of Technology,
Ananthapuram,
Andhra Pradesh, India.

Mr. N. PHANI RAJA RAO
Asst. Prof & HOD
Sri Venkateswara Institute
of Technology,
Ananthapuram,
Andhra Pradesh, India.

Abstract-

This paper investigates the parameters affecting the roughness of surfaces produced in the turning process for the various materials studied by researchers. Design of experiments were conducted for the analysis of the influence of the turning parameters such as cutting speed, feed rate and depth of cut on the surface roughness. The results of the machining experiments were used to characterize the main factors affecting surface roughness by the Analysis of Variance Taguchimethod Taguchi's parametric design is the effective tool for robust design it offers a simple and systematic qualitative optimal design to a relatively low cost. The Taguchi method of off-line (Engineering) quality control encompasses all stages of product/process development. However the key element for achieving high quality at low cost is Design of Experiments (DOE). In this paper Taguchi's (DOE) approach used by many researchers to analyze the effect of process parameters like cutting speed, feed, and depth of cut on Surface Roughness and to obtain an optimal setting of these parameters that may result in good surface finish, has been discussed.

1INTRODUCTION

Hard machining comprises 58HRC to 68HRC hardness for the process itself.

Hard machining uses hardened alloy steel,
Tool steels, case-hardened steels, nitride
Irons, hard-chrome-coated steels, and heat-treated powder metallurgical parts..

1.1ADVANTAGESOFHARDMACHINING

- ➢ This method allows for the simple machining of intricate part shapes.
- ➢ This technique allows for rapid changing between component kinds.

- Numerous operations can be carried out in a single setup.
- The rate of metal removal is very high.
- This method can be carried out on a CNC lathe that is utilised for soft turning.
- Machine tool investment is really minimal.
- The method creates ecofriendly metal chips.
- Many times, coolant is not needed.
- Little tool inventory is needed..

1.2 LIMITATIONSOFHARDMACHINING

- Hard machining requires more expensive tooling than grinding does.
- For hard turning, keep L/D low. Unsupported long, thin pieces will clatter at high cutting pressure.
- Hard machining needs a rigid machine. Machine stability provides hard turning precision. Reduce overhangs, tool extensions, shims, and spacers to increase machine stiffness.
- Hard machining involves deciding whether to utilise coolants. Gears and interrupted cuts benefit from dry machining. The insert will break due to thermal stress departing and entering cuts.
- Continuous cutting softens previously machined areas and lessens hardness, making material easier to cut. Dry machining makes handling and in-process gauging difficult, hence water-based coolants should be employed.
- As tool wear increases, surface polish worsens.
- Hard machining creates a thin, tougher coating called the "white layer." Tool wear thickens it. Bearing steel generates a white film that affects contact-pressure bearing races. Loss of bearing white layer.

1.3 VARIATIONS OF HARD MACHINING AND CONVENTIONAL MACHINING FEATURES

- When a workpiece fractures, a chip in the shape of a sawtooth forms. At the work piece's free surface, a crack forms within the shear strain range.
- Hard-machined segmental chips feature a sawtoothed cross section are produced by adiabatic shear in materials that are hard to machine, however these two chips are not identical because they result from separate mechanisms.
- Hard machining has a very tiny shear angle that grows with work load material hardness and is agnostic of tool rake angle, while typical machining has a large shear angle.
- Hard machining has a larger radial (thrust) component than tangential (power). As flanks wear, the gap widens.
- The tool rake angle affects the tangential (power) and radial (push) parts. The components don't get harder with material hardness when the rake angle is zero. These components are less effective at a rake angle of -20 degrees when the work material is harder.
- For harsh machining, the chip compression ratio is equal to 2.
- Radial and tangential flank wear affects many sections. When flank wear reaches 0.2mm, radial component triples.

1.4 FACTORSDISTINGUISHINGHARDMACHINING

The changes in energy balance between hard machining and ordinary machining should be studied. The formula that is used for the

Cutting energy balance:

Pc=Fc.V=Ppd+Pfr+Pjf+Pch

WhereFc= tangential cutting power.

V =is the cutting rate.

Ppd= plastic deformation power Pfr means "tool chip interface power"

Pjf =means power released from a tool to a thing.

Pch =estimates the effort required to create fresh surfaces.

Following are results from a comparison of the energy balance during normal and hard milling of AISI 52100.

1. Hard machining uses the most power on the tool's workpiece surface, whereas conventional machining uses the reverse.

2. In hard machining, a lot of power is spent on the creation of fresh surfaces.

3. There is also a lot of energy used in the deformation of the layer being removed..

1.5 HARDTURNING

Hard turning is a technique that does away with the need for grinding operations. Surface finish Ra of 0.4 to 0.8 micrometres, roundness of around 2 to 5 micrometres, and diameter tolerance of +/-3 to 7 micrometres are all results of a proper hard turning process. Soft-turning equipment can also hard-turn. Hard turning begins with 47 HRC materials but is usually done on 60 HRC or higher.

Tool steel, case-hardened steel, bearing steel, Inconel, Haste alloy, stellite, and other exotic materials are also included in the list of materials needed for hard turning. Even when long, thin parts have headstock support, high cutting pressure causes chatter. So, the length to diameter ratio (L/D) for unsupported work pieces shouldn't be greater than 4:1. Stiffness measures hard turning ability.

For hard turning, system stiffness is more important than machine rigidity. Shims and spacers should be avoided if the rigidity of the system is to be increased. Overhangs, tool extensions, and part extensions should also be reduced. The idea is to keep everything as near as you can to the turret or spindle. Using coolant or not is the primary challenge in hard turning. The majority time, hard turning is done dry.

Rotating without coolant will heat a part. Process gauging is hard. The machined item is quickly cooled with high-pressure coolant.

Airborne cherry red chips create issues. Hard turning uses water-based coolants. If the chip is studied before, during, and after cutting, it can be verified if hard turning was used. Orange chips should flow like ribbon while continuous cutting. Crunching a cooled chip shows that enough heat was created.

1.6 TYPESOFTOOLWEAR

A cutting tool could break down in the middle of the process for a variety of reasons, including softening, brittle fracture, rapid mechanical load changes or shocks, gradual wear in the working piece, etc. Due to inadequate cutting edge strength, the stresses that result from the work material's resistance at the current strain rate and temperature cause the cutting edge to round off. As flank contact increases, effluent is driven past the surface. If the ratio of tool-to-chip hardness is altered with the same cutting temperature and strain-rate, "shape stability" is attained. Brittle fractures are induced by shocks, such as intermittent cutting, rapid freezing, chattering, etc. By carefully setting the cutting parameters (feed, depth of cut, etc.) and raising the tool's wedge angle, brittle fractures can be averted. Even if the cutting edge has reached "form stability" or brittle fracture has been resisted, cutting tools still fail via wear under normal cutting conditions. This wear is caused by chip-tool or work-tool interaction.

The cutting tool breaks in two places after some use. The flank wear below the cutting edge creates a parallel wear land. On the tool face, wear appears as a "crater" a certain distance from the cutting edge.

Greater production speeds with acceptable dimensional precision and finish are correlated with economies of scale in the metal industry. Wear reduces the cutting tool's usable life. The wear on cutting tools thus has a direct impact on productivity. The main focus of machine ability study is to look at the basic wear test that controls tool life..

1.7 CAUSESOFTOOLWEAR

Mechanical and thermal abrasion induce tool wear. The roles of these two actions vary under different cutting situations. Low cutting speeds and good machinability favour mechanical wear. High cutting speeds on low-machinability workpieces cause thermal wear.

Thermal wear is caused by diffusion, oxidation, and the change in tool mechanical properties caused by high cutting rates. Fast relative motion of chips on the cutting tool's face causes friction. The workpiece also causes friction on the flanks.

Even if the tool is harder than the workpiece, friction and wear occur, but not evenly. The cutting tool wear, which is a decrease in weight or mass of the sliding pairs, can be classified by the likely process of wear:

- ➢ Such as adhesion and abrasion, are mechanical actions.
- ➢ Dispersion thermochemical process.
- ➢ A local electrochemical process like galvanic action.

Mechanical wear contributes significantly to total wear volume, especially at low sliding or rubbing speeds, and occurs in two ways when rubbing surfaces are not in an active chemical environment and electrical interaction is absent.

- ➢ Abrasion from hard elements such isolated carbides and inclusion plough the softer matrix.
- ➢ Over the rubbing surfaces that were put under pressure, adhesion and the formation of metallic bonds occurred. These bonds then ruptured, which was followed by the transfer of elementary particles.
- ➢ Wear is concentrated in the area close to the cutting edge and causes a crater to emerge.

Depending on the mechanism of tool wear, there are several types of wear.

- ➢ Flanking wear
- ➢ Wear on the area of the face where the chip was removed.
- ➢ Actual wear to the cutting edge.
- ➢ Nasal wear and tear.
- ➢ Wear and crater formation.
- ➢ Cutting edge cracks that appear when machining operations are paused.

1.8 WEAR OF TOOLS MECHANISMS

Evidence shows that wear is complex and driven by several factors. Wear causes don't always act the same under similar cutting conditions. Wear causes are known. Past years saw many research advances. Most studies think there are at least five major causes of wear:

- Abrasive action of the work material's hard particles
- Cutting edge damage due to metals
- Chemical of the hard particles themselves and the contact surfaces of the cutting tool. Cutting heat or cutting speed affects how these causes' relative effect are altered

Other possible causes, like oxidation and chemical corrosion in the tool work contact zone, have also been looked into.

Cutting temperature is the major part causing tool wear. Cutting temperatures is critical for two primary reasons among the four basic causes of wear, where temperature has a major impact on all but one.

(1) (1) Above a certain critical temperature, the bulk of tool materials soon lose their strength, hardness, and resistance to abrasion.

(2) (2) As temperature increases past the critical level, the rate of diffusion between work and tool materials increases very fast.

1.9 TOOLFAILURE

Failure occurs when a cutting tool can't produce parts. The machining goal affects the failure point and degree of wear. Surface quality, integrity, cutting forces, cutting power, and production rates are tool failure criteria.

In Fig. 2.1a&b&c, the constituents of a cutting tool's wear are depicted.

the machining goal. Tool failure criteria also include factors like Quality, dimensions, cutting forces, horsepower, and production rates. In Fig. 2.1a&b&c, the pieces of a cutting tool's wear are depicted.

A certain amount of cutting edge collapse is related to tool failure. Over time, there is a gradual collapse of this. The tool may break mechanical or chip under the stress of the cutting forces if rigidity is absent or if the tool geometry is inappropriate, providing the cutting edge with sufficient support [35]. This isn't really a wear event due to the right application and design, it can be removed or at the very least reduced.

There are three main areas on the tool where wear might occur as a result of direct contact with the material:

Face, flank, and nose come first..

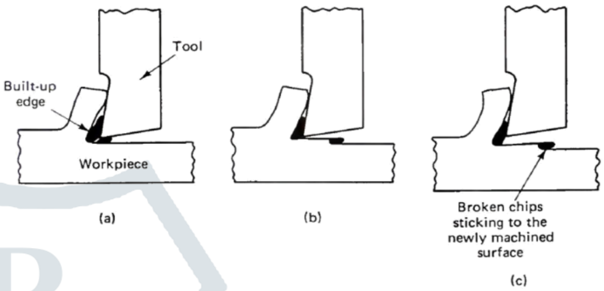

Fig1.Variouselementsofwearacuttingtool

LITERATUREREVIEW

Singh and Rao evaluated the effect of cut depth and tool geometry on bearing steel surface roughness (AISI 52100). This study uses mixed ceramic inserts with different nose radii and effective rake angles (SNGA). This study found that feed, nose radius, and cutting velocity affect S.R. the most. The interplay of nose radius and effective rake angle has a big impact on S.R. RSM creates math models.

Tugrul Ozel studied the effects of cutting edge geometry, work piece hardness, feed, and cutting speed on AISI H13 steel surface roughness and force. This study uses four-component, two-level factorial ceramics. Hardness, edge geometry, feed, and cutting speed are the factors. Hard turning measured cutting force, feed force, thrust force, and surface roughness. In the study, surface roughness is affected by workpiece hardness, cutting edge geometry, feed, and cutting speed. Poor and fine edge geometry boost S.R. Speed, hardness, and edge geometry affect force components.

B. Fnides conducted the experiment to build a statistical model of surface roughness in hard turning X38CrMo5-1. This 50HRC steel is machined with a metal Cr-Mo-V mixed ceramic tool (cc650, 70% Al2O3 + 30% Tic). 27 tests used 33 full factorial designs.

The variables are set at low, medium, and high levels. Multiple regression is used to construct mathematical models that show how each element of the cutting regime affects surface roughness. Finally, the results show that cutting speed is second only to feed rate in affecting surface roughness. Surface roughness is not severely altered by cut depth.

For them, Dr. G. Hrinath Gowd created a second order polynomial model based on his research on Fx, Fy, Fz, and S.R. Cutting parameters are the main cause of turning issues (Fx, Fy, Fz and S.R.). The results of tests show that speed, feed, and depth of cut have a major effect on cutting force, feed force, thurst force, and surface roughness. Use is made of mathematical models for the estimate of Fx, Fy, Fz, and S.R. and RSM.

K. Adarsh Kumar studied how spindle speed, feed rate, and cut depth affect EN-8 surface finish. Experimental measurements were assessed using ANOVA and multiple regression. Cemented carbide inserts and multiple regression measure surface roughness. Create a link between cutting speed, feed, and depth of cut to optimise S.R.

Salvi studied 20MnCr5's hard turning. This study aims to determine the ideal conditions for turning 20MnCr5 steel with minimal surface roughness. This method involves cutting. Orthogonal array, SNR, and ANOVA are utilised to assess cutting features. Cutting speed causes decreased surface roughness, followed by feed rate, according to the experiment. This investigation used ceramic-based TNGA160404 cutting insert.

F. Puh employed a PCBN tool, SN ratio, and CERAMICS to analyse cutting parameters (speed, feed, and depth of cut) while considering S.R. Using this data, he optimised hard turning AISI 4142. Multiple regression analysis found first- and second-order linear surface roughness prediction models.

TOOLWEARANDSURFACEROUGHNESS-OVERVIEW

3.1 SurfaceRoughness

The current machine era has greatly advanced as a result of greater knowledge and ongoing surface texture changes. Smoother, tougher surfaces are required due to the increased strength and bearing load. The operation of machine parts, load carrying capacity, tool life, fatigue life, bearing corrosion, and wear properties are all impacted by the surface finish.

Failure brought on by fatigue always happens at sharp corners where tension is focused. Any surface irregularity begins at a sharp corner, and that component fails first. Surface asymmetry at the non-working surface affects failure as well. Different requirements call for various surface types, hence quantitative surface texture measurement is crucial. The surface flaws take the form of a series of hills and valleys that vary in height and spacing.

Minor variations from ideal conditions prevent perfect chip removal milling. Surface irregularities can be divided into four sorts due to less-than-ideal conditions.

- First of all: These deviations are caused by flaws in the machine tool itself, such as crooked guide ways on which the tool post is travelling. This category also includes irregularities caused by the work being bent by cutting forces and the weight of the material.

- Second order: Vibrations of any kind, such as chatter marks, are the cause of this level of abnormalities.

- Thirdly, even if the machine is flawless and fully free of vibrations, the machining process' inherent flaws can still result in certain errors. For instance, the cutting tool feedmark.

- Fourth order: This sort of defects is caused by the material rupturing during the chip separation.

- Additionally, these four order anomalies can be split into two groups

- The first group consists of periodic irregularities with a large wavelength caused by mechanical disturbances in the generating setup. These mistakes, known as macro-geometrical errors, comprise first- and second-order abnormalities. These flaws are also known as secondary texture or waviness. The second category consists of small-wavelength irregularities brought on by the cutting element's direct contact to the material or by additional disturbances like wear, corrosion, or friction. Roughness or waviness are terms used to describe errors in this category..

3.1.1 TermsUsedInSurfaceFinish

- Roughness: This is a result of irregular surface structures that come from the natural actions of the production process.
- Waviness is caused by work piece deflection or machine vibrations.
- Flaws are irregularities created in a surface at a single location or at widely variable intervals.
- The line around which roughness is measured is known as the centre line.
- The length of the profile required for the evaluation of the surface roughness parameters is known as the traversing length. One or more sampling lengths are included in the traversal length.
- Sampling length is the profile length needed to evaluate anomalies.
- The mean line of the profile splits the effective profile so the sum of the squares of the distances between the effective points and the mean line is as minimal as feasible across the sampling duration.
- The centre line of the profile is parallel to the profile's general direction and where the profile's regions above and below the line are equal.

3.1.2 MethodsofMeasuringSurfaceRoughness

There are two ways to gauge how well a machined object is finished.

1.The first one is surface inspection using comparative techniques.

2.Instrumentation taken directly

(i) Methods for surface inspection by comparison

Using analytical methods, surface texture is assessed. These methods are wrong if tested on surfaces made with other methods. Similar methods include:

- Torch exam
- Form of direct
- Scratch exam

- Microscopic analysis
- Surface images
- Micro-Interferometer
- Surface multimeter by Wallace
- Light intensity from reflect

(ii) Measurement using a direct instrument

The following are the stylus probing instruments: This method can be used to measure the surface finish of any surface. Electrical principles are applied in this form of measurement, and the device is of the stylus probe variety. These electrical devices offer two distinct types. The first kind of operation is carrier variation. Due to high frequency carrier current, the stylus moves while exploring the surface. The second type employs a voltage-generating device.

1.Profilometer
2.TheTomlinsonsurfacemeter
3.TheTaylor-HobsonTalysurf
4.Stylus

Taylor-Hobson-only In our experiment, we use Talysurf to calculate surface roughness.

3.2. ToolWearinTurning

Turning requires a consistent cutting force, thus it's continuous. Friction and shear deformation heat the tool/chip contact constantly. High tool rake face temperature causes turning wear. Austenitic steels, super alloys, and titanium alloys reach 600 degrees. Turning has four wear mechanisms. They're underneath:-

(i) Craterwear
(ii) Notchwear
(iii) Flankwear
(iv) Adhesion

Crater wear: Chemical or metallurgical wear. Small tool rake particles adhere to newly chipped surfaces, giving cratering. Mechanical friction causes a scar-like structure to emerge on the rake face. In reduced materials like titanium alloys, rolling creates crater wear.

Notch wear: Just where the main cutting edge meets the work surface, flank and rake wear occur. This wear occurs in materials that harden due to mechanical stresses. When a tool touches a freshly machined surface, the outer layer gets harder. Notch wear occurs while turning austenitic steels and nickel-based alloys.

Flank wear: This is flank wear. Major and minor cutting edges have uneven wear land. Working with hard materials causes this wear since there is no chemical affinity. Abrasion causes this wear.

Adhesion: Pressure and heat fuse the chip's new surface to the tool rake face. Metals materials weld better, resulting in a thick adhesive layer and ripping of the softer rubbing surface at high wear rates. Dry aluminium wears like this. Hard machining is does not cause this wear.

Wear curve: For various cutting speeds, the following curve displays mean flank wear (VB) over time. As shown in fig. 3.5, this wear curve is divided into three regions.

Initialwearregion:The sharp new edge wore away quickly in this area. The wear size in this area is VB = 0.05-0.1 mm..

SteadyWearRegion:The rate of wear is constant and goes up in this area. From VB=0.05 to 0.6 mm in this zone onward.

SevereWear Region: Tools wear out quite quickly in this area. When this zone is reached, the worn tool must be replaced one, or it must be honed to control tool breakage.

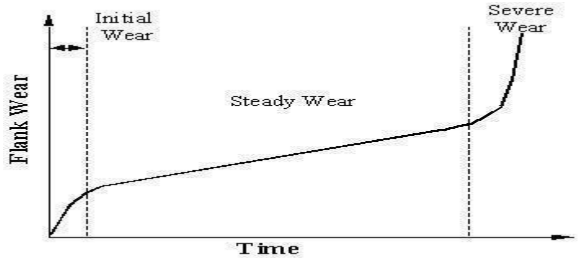

Fig-2:Development offlankwearwithrespecttotime

4.1. Work piece material:

EXPERIMENTALDETAILS

The chrome-moly alloy used in the work piece was created by Kalunga's Cast Profile Pvt. It has a 50 mm diameter and a 600 mm length. Heating is used to raise its hardness to 48 HRC. The image of the work piece's material and the CR-MO alloy's chemical make-up shown in fig. 4.1 below:

Fig-3: Workpiecematerial(Cr-Moroundbar)

Bar length for the Cr-Mo alloy is 600 mm.

50 mm is the bar's diameter.

Material hardness = 48 HRC

Cr-Mo alloy's chemical make-up

Experiment used four cutting inserts. Since each insert has eight edges, 27 tests use all eight of the first three inserts' edges and three of the last. Insert SNMG 120408. Inserts are Tic-coated carbide. Fig4.2 shows each experiment insert and its features and geometry. (a), (b),(c),(d) (d) (d):nsert-1[a] Insert-2[b]Insert-3[c] Insert-4[d]

Fig4.Cuttinginserts

Fig-6:a lathe with a workpiece

4.5. In the experiment, a surface roughness tester was used.

Fig-8: Micrometer

RESLTSANDDISCUSSION

5.1. Surface Roughness Main Effect Plots:-

Figs. 7 through 9 illustrate speed vs. mean of surface roughness S/N ratios, feed vs. mean, and depth of cut vs. mean. These graphs favour lower. As speed increases, S/N ratios decline, improving surface quality. Graph 8 shows that feed rate reduces surface roughness and improves surface smoothness. Graph 9 shows that as cut depth increases, surface roughness first declines, then rises. Feed and depth of cut have a considerable impact on roughness, while cutting speed does not.

The apparent friction coefficient doesn't change with chip velocity and inclination. For some components whose sliding friction coefficients don't fluctuate with chip velocity or remain constant, the apparent friction coefficient is altered by inclination angle.

The rake angle from 0 to 100 reduces normal cutting force by 47.65% and friction force by 33.03%. Increasing rake angle increases visual friction. Variations in rake forces are caused by things. First, contact lengths affect visible friction coefficient. The link between contact lengths and rake angle is not explicit since the rake angle affects pressure distribution at the rake face and shear stress and angle at the shear band.

Graph 6.10 shows the sticking-to-total contact length variation with rake angle. As rake angle increases, this ratio fell, thus the sticky contact region's ratio to total contact length also declines. As graph 6.9 shows, this is due to a decrease in the rake face's normal force. The visible friction coefficient reduces as sticking contact length increases. The apparent friction coefficient rises with rake angle due to a higher fraction of sliding length over total contact length.

CeramicsAndResponseTableForPowerConsumption

Table-5.3 shows Tiles' power usage, and table-5.4 shows Response's. DF, SS, MS, F-value, and P-value are listed for CERAMICS. F-statistics stress depth and speed. Cut speed and depth have p-values below 0.05. As shown by the delta statistics in the response table, cutting speed and depth of cut are significant.

CONCLUSION AND FUTUREWORK

6.1. The following results are made about the impact of cutting speed, feed, and depth of cut on the performance of Tic coated carbide tools when milling Cr-Mo alloy.

1. Using Main effect plots of surface roughness, surface finish improves as speed increases and SN ratio decreases. Feed increases produce a fine surface finish because the mean SN ratio drops. Surface decreases from 0.3 to 0.5 mm, but increases from 0.5 to 1 mm.
2. The F-statistics and rank of response table reveal that feed and depth of cut affect surface roughness, with feed having the highest slope vs. mean of SN ratio. Feed and cut depth determine surface roughness.
3. As speed increases, SN/power diminishes. Less power affects speed, feed, and depth of cut since power's SN ratio lowers with feed and depth.
4. Power depends on cutting speed and depth.
5. As speed increases, the mean SN ratio rises, increasing the chip reduction coefficient. Chip reduction coefficient rises from 0.1 to 0.13 then falls from 0.13 to 0.15. Cut depth reduces chip reduction coefficient.
6. Speed and cut depth affect chip reduction coefficient.
7. Tool wear increases from 39.275 m/min to 65.982 m/min and declines to 111.541 m/min. From 0.1 to 0.13 mm/rev, tool wear declines quickly, but it rises slowly from 0.13 to 0.15 mm/rev. From 0.3 to 0.5 mm of cut depth, tool wear increases but remains constant.
8. Cutting depth and speed have a major effect on tool wear.

6.2. Future work:-

1. Future studies may use other hard materials, such as Inconel-718, for machining using the same procedure while changing the L-27 orthogonal array design and cutting tools.
2. The experiment may be repeated with different cutting inserts, such as ceramic or

CBN, and the results may be compared to those of the first experiment.

3. Rsm may replace cutting tools in the analytical procedure.

REFERENCES

[1] C. R. Barik and N. K. Mandel, “Parametric Effect and Optimization of Surface Roughness of EN 31 in CNC Dry Turning”, International Journal of Lean Thinking, Volume 3 (2), 54-66, 2012.

[2] D. B. Dallas, “Tool and Manufacturing Engineers Handbook”, 3rd edition, (Society of Manufacturing Engineers; McGraw Hill Book Company, 1976) pp. 1-3 to 5-20.

[3] E. Isakov, “Cutting data for turning of Steel”, Industrial Press Inc., New York, pp. 104, 2009.

[4] M. N. Islam and B. Boswell, “An Investigation of Surface Finish in Dry Turning”, Proceedings of the World Congress on Engineering, Vol. I, WCE 2011, London, U.K, 2011.

[5] D. V. V. Krishan Prasad, “Influence of Cutting Parameters on Turning Process Using ANOVA Analysis”, Research Journal of Engineering Sciences, Vol. 2(9), 1-6, 2013.

[6] N. Kumar and N. Uppal, “A Review on Various Optimization Techniques used in Turning Operation for Improving Surface Roughness”, Mechanica Confab, Vol. 2 (4), 45 – 51, 2013.

[7] P. Kumar, P. B. Barua, J. L. Gaindhar, “Quality Optimization (Multi-characteristics) through Taguchi’s Technique and Utility Concept”, Quality and Reliability Engineering International, 16, 475 – 485, 2000.

[8] M. Nalbant, H. Gokkaya, G. Sur, “Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning”, Materials and Design, 28, 1379–1385, 2007.

[9] J. Paulo Davim, “A note on the determination of optimal cutting conditions for surface finish obtained in turning using design of experiments”, Journal of Materials Processing Technology, 16,

[10] L. L. R. Rodrigues, A. N. Kantharaj, B. Kantharaj, W. R. C. Freitas, B.R.N. Murthy, “Effect of Cutting Parameters on Surface Roughness and Cutting Force in Turning Mild Steel”, Research Journal of Recent Sciences, Vol. 1(10), 19-26, 2012. [11] P. J. Ross, “Taguchi Techniques for Quality Engineering”, 1st edition, (McGraw-Hill Book Company, New York), 118-124, 1988. [12] R. K. Roy, “A Primer on the Taguchi Method, 1st edition, (Van Nostrand ReinholdRiza Mot