INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Optimization of CNC Turning Process Parameters for Prediction of Surface Roughness by Factorial Experimentation

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Abstract:
In the present investigation an attempt is made to evaluate the effect of certain cutting variables on surface roughness in plain turning of medium carbon steel AISI 1055 under cutting condition. Cutting speed, depth of cut, feed and cutting flow rate are selected as the influencing parameters. The experiments are conducted by factorial experimentation medium carbon steel AISI 1055 was machined using adhesive bonded tool and compared the performance with brazed tool. The cutting condition of turning parameters was determined by Design of experiment method to find the optimal levels and to analyze the effect on the turning parameters.

Key words: *Surface Roughness, Comparing tool, Adhesive bonded tool, Turning Process*

1. Introduction

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 that produces cylindrical parts [24]. Today's fast changing manufacturing environment requires the application of optimization techniques in metal cutting processes to effectively respond to severe competitiveness and to meet the increasing demand of customizable quality product (low cost, high quality, easily deliverable) in the market[3]. Machining vibration is important in metal cutting operations which may affect the quality characteristics. The machine tool operators always face the problem in turning process. Machine tool condition, job clamping, tool and work piece geometry and cutting parameters are the major reasons for occurrence of this problem. Vibration in machine tool is directly affecting the surface finish of the work material in turning process. So vibration of a machine tool is one of the major factors limiting its performance [2]. In machining, there has been recently and intensive computation focusing on surface roughness at international level. This computation can be observed in turning processes especially in plane and automotive industry by increasing the alternative solutions for obtaining more proper surface roughness [4]. So it becomes important to study the effect of machining parameters on multiple quality characteristics like surface roughness and vibration etc. [21]

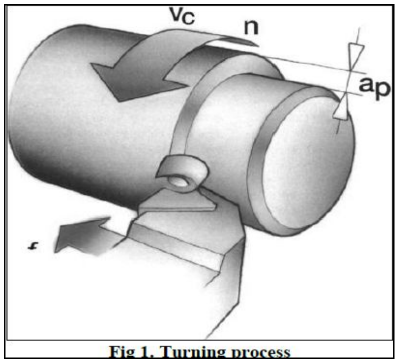

Fig 1. Turning process

Figure 1

2. 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:

- The machining variables which include a
  - Cutting speed
  - Feed, and
  - Depth of cut.
- The tool geometry
  Some geometric factors which affect achieved Surface finish include:
  - Nose radius
  - Rake angle
  - Side cutting edge angle, and
  - Cutting edge.
- Work piece and tool material combination and their mechanical properties
- Quality and type of the machine tool used,
- Auxiliary tooling, and lubricant used, and
- Vibrations between the work piece, machine tool and cutting tool.[24]

3. Literature Review

H.Joardar, N.S.Das[1] An experimentation study to effect of process parameters in turning of LM6/SiCp metal matrix composite and its prediction using response surface methodology. Muhammad Munawar, Hassan Iqbal[2] Optimization of Surface Finish in Turning Operation by Considering the Machine Tool. Mr. Ballal Yuvaraj P., Dr. Inamdar K.H., Mr. Patil P.V [3] Application of taguchi method for design of experiments in turning gray cast iron. Süleyman Nes_eli, Süleyman Yaldız, Erol Türkes[4] Optimization of tool geometry parameters for turning operations based on the response surface methodology. Daniel Kirby [5] Feed rate had the highest effect on surface roughness, spindle speed had a moderate effect, and depth of cut had an insignificant effect. Karin Kandananond[6]investigated The best cutting conditions for minimizing surface roughness in a turning process of ferrite stainless steel. Faruk KARACA [7] investigated the machining characteristics of stainless steel in turning process. During experiments, parameters such as cutting speed, feed rate and depth of cut were changed to explore their effect on the surface roughness, tool flank wear and tool chip interface temperature. Brian Boswell [8] investigated the three major cutting parameters—cutting speed, feed rate, and depth of cut—that affect the surface finish of turned parts in dry turning. Feed rate has a dominant effect on surface finish; the interaction between cutting speed and feed rate also plays a major role which is influenced by the properties of work material. Dr.S.S.Chaudhari[9] MQL is a technique that could reduce many cutting problems coming from high consumptions of lubricant, like high machining costs or environmental and worker health problems. M Venkata Ramana [10] the synthetic oil as a cutting fluid in machining of Ti6Al4V alloy shows advantage in minimizing the surface roughness. G. H. Senussi [11] The interaction effect between cutting speed and feed rate on chip micro-hardness is reported easily so, chip micro-hardness is higher at high level of feed rate [0.20 mm/rev], but it is better when increasing in cutting speed [200 m/min]. LB Abhang [12] A reliable surface roughness model for steel turning was developed using RSM and incorporated cutting speed, feed rate, depth of cut, and the tool nose radius. Al-Ahmari [13] in this paper, empirical models for prediction of machinability models (tool life, cutting force and surface roughness) have been developed based on cutting experiments. Hari Singh [14] A design of experiment Based approach is adopted to obtain the optimal setting of turning process parameter that may yield optimum tool wear. Suleyman Neseli [15] Investigation focuses on the influence of tool geometry on the surface finish obtained in turning of AISI 1040 steel. S.R.Carvalho [16] in this paper the thermal model is obtained by numerical solution of the transient three-dimensional heat diffusion equation that consider both the tool and the tool holder assembly. To determine the solution equation the finite volume method is used. Changing thermal properties with the temperature and heat lossess by convection are also considered. Several cutting tests using cemented carbide toolswere perform in order to check the model and to verify the influence of cutting parameters on temperature field. Saurav Datta [17] this paper deal with optimization of multiple surface roughness parameters in search of an optical parametric combination capable of producing desired surface quality of MS turned steel was investigated. Viktor Astakhov [18] In this paper the optimal cutting temperature, the increase of cutting feed leads to increased dimensional tool life. Arastirma Makalesi [19] In this paper the effect of turning parameters such as cutting speed, feed and depth of cut on machining characterstics of AISI 304 steel was investigated. M.N Islam [20] In this paper, feed rate has a dominant effect of surface finish; the interaction between cutting speed and feed rate also play a major role which is influenced by the properties of work material. A.K. Baldoukas [21] Experimental Investigation of the Effect of Cutting Depth, Tool Rake Angle and Work piece Material Type on the Main Cutting Force during a Turning Process. Cutting forces and surface finish when machining medium hardness steel using CBN tools (International Journal of Machine Tools & Manufacture, 11 November 1997). Determination of optimum process parameter during turning 0f AISI 304 austenitic stainless steel.(International journal of lean Thinking vol 3 Issue1 (June 2012).

4. Factorial Experimentation

Factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental units take on all possible combinations of these levels across all such factors. A full factorial design may also be called a fully crossed design.

4.1. Factors Determining the Process

- X_1 = Cutting Speed, m/min.
- X_2 = Feed, mm/rev.
- X_3 = Depth of Cut, mm

4.2. Optimization Parameters

- Y = MRR mm^3/s
- S = Surface Finish. (µm).

4.3. Number of Trials

The number of trials is given by the formula:

- $A = B^K$

Where;

- A = No. of trials.
- B = No of levels.
- K = No. of factor.

Since, it is a two level experiment and number of factors are - 3
Therefore, Number of Trials (A) = $2^3 = 8$.

5. Experimental Setup

5.1. Selection of work and tool material

<u>5.1.1. Test Specimen</u>

The selected work piece material for this experiment is medium carbon steel (AISI 1055). The chemical composition of medium carbon steel (AISI 1055) work piece is shown below. [21]

C	SI	MN	P	S	Cu	Cr	Ni
0.56	0.19	0.82	0.12	0.04	0.06	0.15	0.08

Figure 2

<u>5.1.2. Cutting Tool</u>

The recently developed tool materials like adhesive bonded tool have improved the productivity levels of difficult to machine materials. The adhesive bonded tool reduces wear and tear between tool insert and workpiece. Thus adhesive bonded tool was selected for turning of AISI 1055 Steel. Cutting Tool used is carbide insert tool.

Figure 3: Adhesive bonded tool

6. Selection of Adhesive bond

- Adhesive bonded is a single component toughened heat curing epoxy adhesive, which exhibits very exceptional bond strength on curing.
- The easiness of application allows automation of lines, with labour saving equipment, thereby improving the work efficiency.
- Since the non-volatile content is very low there is very little shrinkage on setting. In addition cured adhesive has excellent resistance to oils and solvents.
- The product has been specially developed for magnet bonding in electronic industries.
- The easiness of application allows automation of production lines, with labour saving equipment.
- 100% reactive systems, which does not shrink over a period of time.
- Withstands high temperature.
- Heat cure systems
- No mixing or degassing
- Excellent bonding strength
- Good mechanical strength
- Highly resistance to acids, bases and many solvents.

7. Experimental Design

The aim of the experiments was to analyze the effect of turning parameters on the surface roughness of AISI 1055 Steel. Table shows the number and levels of control parameters used. The control factor (turning parameters) were within the range specified by manufacturer.[23] On the other hand , each experiment was carried out with a fresh cutting tool in order to prevent the negative effect of tool wear on surface roughness.[22]

Code	Control factors	Levels		
A	DOC(mm)	0.4	0.8	1.2
B	C.S(m/min)	40	71	102
C	Feed(mm/rev)	0.04	0.095	0.15

Table 1: Control Factors Levels of Finish Turning Process

Sr.	A	B	C	Ra(μm)	MRR(mm^3/min)
1	1	1	1	0.88	2392.38
2	1	3	1	1.03	10586.29
3	1	1	3	4.94	7177.14
4	1	3	3	4.51	31758.86
5	3	1	1	1.16	7131.43
6	3	3	1	1.02	31556.57
7	3	1	3	5.02	21394.29
8	3	3	3	4.02	94669.71

Table 2: Experimental Result for surface roughness (Bonded Tool)

Sr.	A	B	C	Ra(μm)	MRR(mm^3/min)
1	1	1	1	0.93	21105.14
2	1	3	1	1.11	10114.10
3	1	1	3	5.01	6902.13
4	1	3	3	4.78	31126.66
5	3	1	1	1.31	6901.11
6	3	3	1	1.11	31002.81
7	3	1	3	5.27	20241.37
8	3	3	3	4.51	94219.61

Table 3: Experimental Result for surface roughness (Brazed Tool)

The experiment was performed on CNC and lathe machine as per experimental scheme in which the work piece was fixed. Then according to the experiment designed the cutting parameters are adjusted in the CNC and lathe machine. The work piece was given initial roughing pass. Sixteen equal parts of 50mm Diameter and 150mm length were cut and arrange for experimentation. So taking the different parameters and the readings are taken for analysis. The sixteen experiments were performed by using brazed tool and adhesive bonded tool. Then Compare the performance of bonded and brazed tools in the turning operation. Different setting of parameters and after the experimentation surface roughness was measured by probe type advance surface roughness tester.

8. Conclusion

From the above, one can use the Adhesive bonded tool for optimizing the turning process parameters like speed, feed, and depth of cut, and type of tool, materials of tool and work piece and cutting fluids etc for minimizing the surface roughness and maximize the tool life by experimental setup. Factorial experimentation will help to finalize the number of levels and thus finalize the number of experiments. Also the signal to noise ratio will help to observe the behavior of quality characteristics of work piece.

9. References

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