The International Journal of Engineering And Science (IJES)
||Volume|| 2 ||Issue|| 1 ||Pages|| 103-113 ||2013||
ISSN: 2319 – 1813 ISBN: 2319 – 1805

Optimization of Different Performance Parameters i.e. Surface Roughness, Tool Wear Rate & Material Removal Rate with the Selection of Various Process Parameters Such as Speed Rate, Feed Rate, Specimen Wear , Depth Of Cut in CNC Turning of EN24 Alloy Steel – An Empirical Approach

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Abstract

This project is based upon the empirical study which means it is derived from experiment and observation rather than theory. For the fulfillment of objective our first motive is selection of cutting tool & work tool material & geometry, selection of various process and performance parameters after parameter selection aims to study various techniques for the optimization for that purpose literature review and industrial survey is conducted. After this next objective is to study the process and machining parameters for the performance characteristics of turning operation on CNC using different grades of Tungsten Carbide and with varying properties & surface roughness testing of work piece material to be carried out after machining. After testing optimization and compare the Effect of cutting parameters on surface roughness of different selected geometry on EN-24 alloy steel by using empirical approach i.e. Taguchi Analysis using Statistical Software. In the end also aims to calculate Tool Wear Rate (TWR) & Material Removal Rate (MRR) related with the performance parameters based upon the experimental investigation. Thus this study helps to compare the results in terms of effectiveness of the performance of different grades of Tungsten Carbide by varying process parameters.

Keywords - Cutting Tool, Turning, Surface Roughness, MRR, TWR, Tool Steels, EN-24, Taguchi

Date of Submission: 20, December, 2012 ⟺ Date of Publication: 05, January 2013

I. Recent Trends in Manufacturing

The recent developments in science and technology have put tremendous pressure on manufacturing industries. The manufacturing industries are trying to decrease the cutting costs, increase the quality of the machined parts and machine more difficult materials. Machining efficiency is improved by reducing the machining time with high speed machining. When cutting ferrous and hard to machine materials such as steels, cast iron and super alloys, softening temperature and the chemical stability of the tool material limits the cutting speed. High speed machining has been the main objective of the Mechanical Engineering through ages. The trend to increase productivity has been the instrumental in invention of newer and newer cutting tools with respect to material and designs.

EN24 is a high quality, high tensile, alloy steel and finds its typical applications in the manufacturing of automobile and machine tool parts. Properties of EN24 steel, like low specific heat, and tendency to strain-harden and diffuse between tool and work material, give rise to certain problems in its machining such as large cutting forces, high cutting tool temperatures, poor surface finish and built-up edge formation. This material is thus difficult to machine. [1].The purpose of metal cutting operation is commonly called machining is to produce a desired shape, size and finish of a component by removing the excess metal in the form of chips from rough block of material. Metal cutting processes in general should be carried out at high speeds and feeds with the least cutting effort at a minimum cost.

1.1 Tool Steels

Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools. Tool steel is generally used in a heat-treated state. With carbon content between 0.7% and 1.5%, tool steels are manufactured under carefully controlled conditions to produce the required quality.

The manganese content is often kept low to minimize the possibility of cracking during water quenching. However, proper heat treating of these steels is important for adequate performance, and there are many suppliers who provide tooling blanks intended for oil quenching. Recommended Tool & Work Material Combinations as shown in Table 1.

Table 1 Recommended Tool & Work Material Combination

Material	Soft Non-ferrous [Al,Cu]	Carbon/Low alloy steels	Hardened tool and die steels	Cast iron	Nickel-based alloys	Titanium alloys
High Speed Steel	All right in some conditions/ Possible But not Advisable	All right in some conditions/ Possible But not Advisable	**To be avoided**	Possible But not Advisable / To be avoided	Possible But not Advisable / To be avoided	Possible But not Advisable / To be avoided
Carbide [Inc. Coated]	All right in some conditions	**Good / All right in some conditions**	Possible But not Advisable	**Good / All right in some conditions**	**Good**	All right in some conditions
Ceramic	**To be avoided**	**Good / All right in some conditions**	All right in some conditions	**Good**	**Good / All right in some conditions**	**To be avoided**
CBN	Possible But not Advisable / To be avoided	**To be avoided**	**Good**	**Good / All right in some conditions**	All right in some conditions	All right in some conditions
PCD	**Good**	**To be avoided**	**To be avoided**	**To be avoided**	**To be avoided**	**Good**

1.2 Tool Materials

Properties of cutting tool materials

- ❖ **Red Hardness or Hot Hardness** – It is the ability of a material to retain its hardness at high temperature.
- ❖ **Toughness** – It relates to the ability of a material to resist shock or impact loads associated with interrupted cuts.
- ❖ **Wear Resistance** – It enables the cutting tool to retain its shape and cutting efficiency.

Other properties are thermal conductivity, specific heat, Hardenability etc.

1.3 Turning Machines

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, work piece, fixture, and cutting tool. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips to create the desired shape.

The turning machines are, of course, every kind of lathes. Lathes used in manufacturing can be classified as engine, turret, automatics, and numerical control etc. CNC Machines Nowadays, more and more Computer Numerical Controlled (CNC) machines are being used in every kind of manufacturing processes. In a CNC machine, functions like program storage, tool offset and tool compensation, program-editing capability, various degree of computation, and the ability to send and receive data from a variety of sources, including remote locations can be easily realized through on board computer. The computer can store multiple-part programs, recalling them as needed for different parts.

Fig1. HMT CNC Lathe Machine

II. Research Background

Literature has been collected from various journals, books, papers etc. & has been reviewed as follows-

Increasing the productivity and the quality of the machined parts are the main challenges of manufacturing industries. This objective requires better management of the machining system. This literature includes information on hard materials, soft materials, and soft and abrasive materials used in turning, coating materials for cutting tools, wear observed during turning operations and surface finish of the machined work piece. Optimization of cutting parameters is valuable in terms of providing high precision and efficient machining. So an attempt is made to optimize machining parameters using coated tools. The user of the machine tool must know how to choose cutting parameters in order to minimize cutting time, cutting force and produce better surface finish under stable conditions.

It is necessary for tool materials to possess high temperature strength. While many ceramic materials such as TiC, Al_2O_3 and TiN possess high temperature strength, they have lower fracture toughness than that of conventional tool materials such as high-speed steels and cemented tungsten carbides. The machining of hard and chemically reactive materials at higher speeds is improved by depositing single and multi layer coatings on conventional tool materials to combine the beneficial properties of ceramics and traditional tool materials [1].

J.A. Ghani et al [2] investigated the wear mechanism of TiN-coated carbide and uncoated cermets tools at various combinations of cutting speed, feed rate, and depth of cut for hardened AISI H13 tool steel. They have observed that the time taken for the cutting edge of TiN-coated carbide tools to initiate cracking and fracturing is longer than that of uncoated cermets tools, especially at the combinations of high cutting speed, feed rate, and depth of cut and at the combinations of low cutting speed, feed rate, and depth of cut, the uncoated cermets tools show more uniform and gradual wear on the flank face than that of the TiN-coated carbide tools.Yong Huang et al [3] have evaluated tool performance in terms of tool life based on the flank wear criterion as a function of cutting conditions, that is, cutting speed, feed, and depth of cut. They found out that cutting speed plays a dominant role in determining the tool performance in terms of tool life, followed by feed and depth of cut, and overall tendencies agree with predictions from the general Taylor tool life equation as well as experimental observations.

Cutting fluid (coolant) is any liquid or gas that is applied to the chip and/or cutting tool to improve cutting performance. A very few cutting operations are performed dry, i.e., without the application of cutting fluids. Generally, it is essential that cutting fluids be applied to all machining operations. The Flow rates can be as low as 10 Liter/min for turning and as 200 Liter/min for face milling.

The selection and proper application of a cutting fluid can produce the following advantage.

- Reduction of tool cost.
- Increased productivity.
- Reduction of labour cost.
- Reduction of power cost.
- High surface Finish.

Table 2 Recommended Cutting Fluids for Various Materials

Material	Drilling	Reaming	Tapping	Turning	Threading	Milling
Aluminum	1.Soluble Oil 2.Kerosene 3.Kerosene and Lard Oil	1.Soluble Oil 2.Kerosene 3.Kerosene and Mineral Oil	1.Soluble Oil 2.Mineral Oil	**1.Soluble Oil**	1.Soluble Oil 2.Kerosence And Lard Oil	1.Soluble Oil 2. Lard Oil 3. Mineral Oil
Brass	1.Dry Soluble Oil 2.Kerosene 3.Lard Oil	1.Dry Soluble Oil	1.Soluble Oil 2..Lard Oil Dry	**1.Soluble Oil**	1.Soluble Oil 2..Lard Oil	1.Soluble Oil Dry
Bronze	1.Dry Soluble Oil 2.Lard Oil 3.Mineral Oil	1.Soluble Oil 2..Lard Oil Dry	1.Soluble Oil 2..Lard Oil Dry	**1.Soluble Oil**	1.Soluble Oil 2..Lard Oil	1.Soluble Oil 2..Lard Oil Dry
Cast Iron	1.Dry Soluble Oil	1.Soluble Oil 2. Mineral Lard Oil	1.Mineral Lard Oil	**1.Soluble Oil 2. Mineral Lard Oil Dry**	1.Dry Sulfurized Oil	1.Dry Soluble Oil
Copper	1. Dry Soluble Or Lard Oil 2.Kerosene 3.Mineral Lard Oil	1.Soluble Oil 2.Lard Oil Dry	1.Mineral Lard Oil 2. Soluble Oil	**1.Soluble Oil**	1.Soluble Oil 2.Lard Oil	1.Soluble Oil Dry
Steel Alloys	1.Soluble Oil 2.Sulfurized Oil 3.Mineral Lard Oil	1.Soluble Oil 2.Mineral Lard Oil	1.Sulfurized Oil 2.Mineral Oil	**1.Soluble Oil**	1.Sulfurized Oil 2.Lard Oil	1.Soluble Oil 2.Mineral Lard Oil
Tool Steel	1.Soluble Oil 2.Sulfurized Oil 3.Mineral Lard Oil	1.Soluble O2il 2.Sulfurized Oil 3.Lard Oil	1.Sulfurized Oil 2.Mineral Lard Oil	**1.Soluble Oil**	1.Sulfurized Oil 2.Lard Oil	1.Soluble Oil 2.Lard Oil

2.1 Gap in Literature

From the literature review, it is observed that less research work has been seen for En24 Alloy Steel in CNC Turning by the Use of different cutting tool geometry. Also very less work has been reported for Cutting tool Rhombus Geometry [Coated, TiN Finished], Rhombus Geometry [Uncoated] & Triangular Geometry [Uncoated].

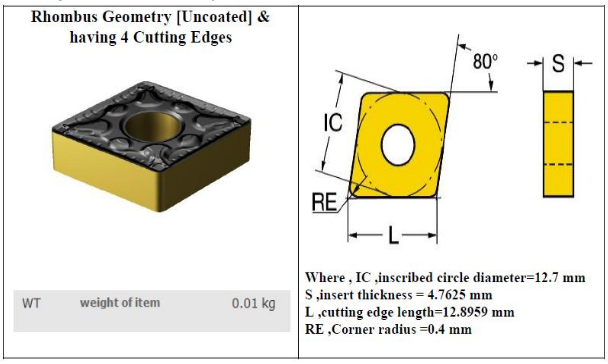


Fig2.Insert CNMG 12 04 04-PM 4225 for T-Max P

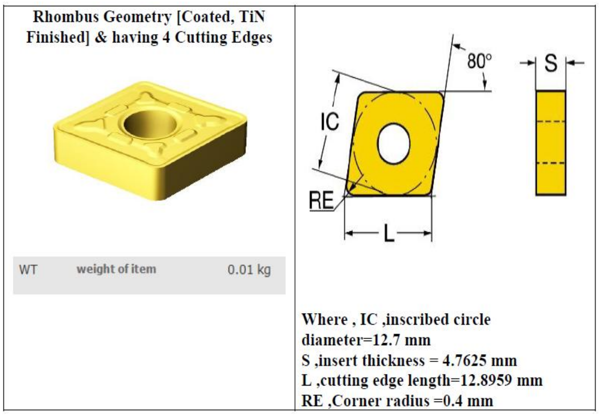


Fig3. Insert CNMG 12 04 04-MF 2025 for T-Max P

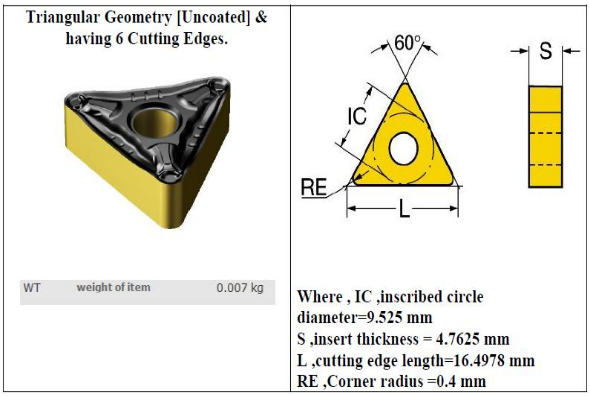


Fig4. Insert TNMG 16 04 04-PM 4225 for T-Max P

It is observed that the effect on machining process of tool geometry on work piece material by the selecting various process parameters with the use of empirical approach have not been explored yet, so it‘s interesting to Optimization of Different Machining Parameters of En24 Alloy Steel in CNC Turning by Use of Taguchi Method. All these aspects will be addressed in research work.

2.2 Coatings

Machining efficiency is improved by reducing the machining time with high speed machining. But the softening temperature and the chemical stability of the tool material limits the cutting speed. When cutting ferrous and hard to machine materials such as steels, cast iron and super alloys, softening temperature and the chemical stability of the tool material limits the cutting speed. Therefore, it is necessary for tool materials to possess good high-temperature mechanical properties and sufficient inertness. Typical constituents of coating are Titanium Carbide (TiC), Titanium Nitride (TiN), Titanium Carbonitride (TiCN) and alumina (Al_2O_3). All these compounds have low solubility in iron and they enable inserts to cut at much higher rate. "Why TiN": The majority of inserts presently used in various metal cutting operations are carbide tools coated with nitrides (TiN, CrN, etc.). TiN coating is usually used as an outermost layer.

- It increases the wear resistance
- Reduces the sticking of the work material.

The golden color of the TiN coating helps in wear detection by allowing the operator to distinguish between a used and a new cutting edge corner

2.3 CNC Turning Parameters

In turning, the speed and motion of the cutting tool is specified through several parameters. These parameters are selected for each operation based upon the work piece material, tool material, tool size, and more. 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.

2.3.1 Process Parameters

Cutting feed - The distance that the cutting tool or work piece advances during one revolution of the spindle, measured in inches per revolution (IPR). In some operations the tool feeds into the work piece and in others the work piece feeds into the tool. For a multi-point tool, the cutting feed is also equal to the feed per tooth, measured in inches per tooth (IPT), and multiplied by the number of teeth on the cutting tool.

Cutting speed - The speed of the work piece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).

Spindle speed - The rotational speed of the spindle and the work piece in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the work piece where the cut is being made. In order to maintain a constant cutting speed, the spindle speed must vary based on the diameter of the cut. If the spindle speed is held constant, then the cutting speed will vary.

Feed rate - The speed of the cutting tool's movement relative to the work piece as the tool makes a cut. The feed rate is measured in inches per minute (IPM) and is the product of the cutting feed (IPR) and the spindle speed (RPM).

2.3.2 Performance Parameters

Table 3 Processing Parameters in Machining

Processing Parameters in Machining		
Cutter Related	**Machine Related**	**Work piece Related**
1.Material 2.Geometry 3.Mounting	1.Cutting fluid type and application method 2.Depth and Width of cut 3.Spindle speed 4.Feed rate	1.Material (Composition , Homogeneity) 2. Geometry (Bar, Block, Casting etc.) 3.Depth of cut 4.Spindle speed 5. Feed rate

Material removal rate: This is a production term usually measured in cubic inches per minute. Increasing this rate will obviously get a part done quicker and therefore possibly for less money, but increasing the material removal rate is often accompanied by increases in tool wear, poor surface finishes, poor tolerances, and other problems. Optimizing the machining process is a very difficult problem.

Tool wear rate: The rate at which the cutting edge of a tool wears away during machining

Surface Finish: The degree of smoothness of a part's surface after it has been manufactured. Surface finish is the result of the surface roughness, waviness, and flaws remaining on the part.

III. Materials and Methods

3.1 Empirical Approach

Empirical Approach means derived from experiment and observation rather than theory.

Step 1 Literature Gap analysis & Conducting Industrial Survey for the selection of Cutting Tool Grades for experiment & Index preparation of objective function
Step 2 Composition testing of Work Piece i.e. EN-24
Step 3 Selections of Cutting Tool Grades
Step 4 Selection of Cutting Tool Holder
Step 5 Specification of Job, Selection of Process for job to be performed on CNC turning & then Preparation of Job
Step 6 Selection Process & Performance Parameters before Machining to be carried out from Literature Survey & Calculation of Performance parameters with the observation of selected process parameters
Step 7 Optimization of Performance Parameters Using Empirical Approach

Step 1 Literature Gap analysis & Conducting Industrial Survey for the selection of Cutting Tool Grades for experiment & Index preparation of objective function

Literature Gap analysis has been collected by referring various journals, books, papers etc. for the purpose of the selection of cutting tool grades ,geometry ,tool holder ,cutting fluid grades commonly used for CNC turning operations and work piece material on which lesser study will be carried out. Another objective selection of Place where to Perform Experiment, Market availability of the recommended tool steel & their Cost Analysis, Time Analysis to complete the experiment etc. More importantly to study various process and performance parameters of CNC Turning Machines & to study various empirical approaches by the optimization. For defining the objective of study to be carried out more effectively and specific we designed Cutting Tool Performance Index **CTPI 2012**.

Step 2 Composition testing of Work Piece[EN-24]

Place of Experiment: Research & Development centre for bicycle & sewing machine, Ludhiana

Type of Sample: Cut Pieces of Steel
Sample Mark: EN-24

Instrument Used: Glow Discharge Spectrometer

Fig5. Marks of Argon Gas on Specimen EN-24

Step 3 Selections of Cutting Tool Grades

Some common types of tools are as follows:
Style A - 0 degree lead-angle turning tools
Style B - 15 degree lead-angle turning tools
Style C - 0 degree square nose tools
Style D - 80 degree included angle pointed-nose tools
Style E - 60 degree included angle pointed-nose tools

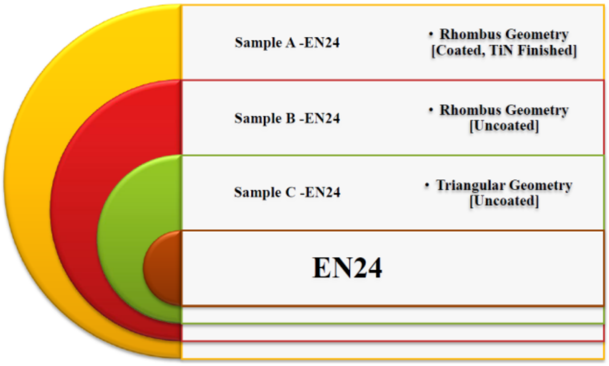


Fig5. Block Diagram of Cutting of Specimen EN-24 Tool Steel for Experimental Work.

Sample Selection:

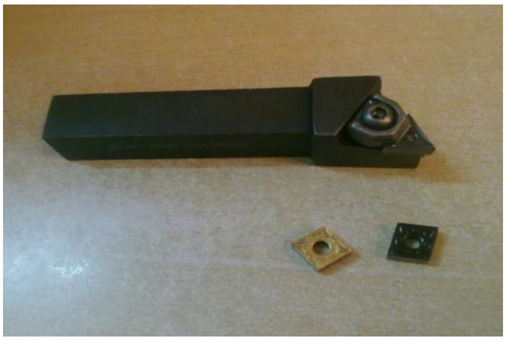
Sample A - Insert CNMG 12 04 04-MF 2025 for T-Max P - Rhombus Geometry [Coated, TiN Finished] & having 4 Cutting Edges [Style D - 80 degree included angle pointed-nose tools]

Sample B - Insert CNMG 12 04 04-PM 4225 for T-Max P - Rhombus Geometry [Uncoated] & having 4 Cutting Edges [Style D - 80 degree included angle pointed-nose tools]

Sample C - Insert TNMG 16 04 04-PM 4225 for T-Max P -Triangular Geometry [Uncoated] & having 6

Cutting Edges. [Style E - 60 degree included angle pointed-nose tools]

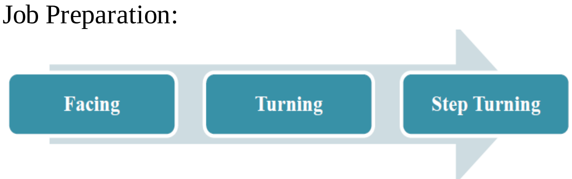
<u>Step 4 Selection of Cutting Tool Holder</u>
Sample Selection: TNMG 20 X 20 Shank



<u>Step 5 Specification of Job, Selection of Process for job to be performed on CNC Turning & then Preparation of Job</u>

Step 1 Drafting, Defining Job Operations & Specification of Size:

Job Preparation:



Size Specification: ϕ50 x 100 mm
Number of Samples: Three

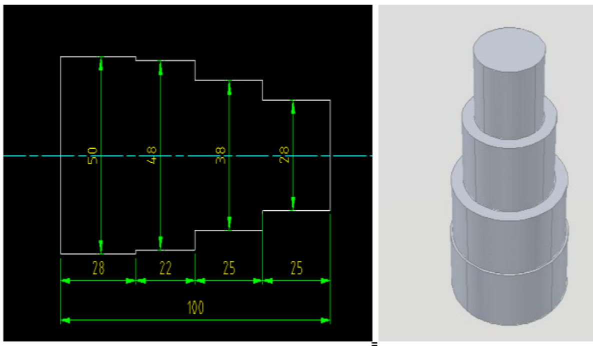


Fig6. 2-D & 3-D View of the Specimen EN-24

For the objective of specification of size we used 2D Software AutoCAD 2010. After the drafting & Process selection machining will be carried out with the help of three grades of selected cutting tools

Step 2 CNC Programming & Job Preparation

Place of Experiment: Research & Development centre for bicycle & sewing machine, Ludhiana

CNC Part Programming is carried out for the objective of Machining & simulation to be carried out.
Sample Mark: **EN-24**

Instrument Used: HMT 3-Axis CNC Turning Machine

<u>Step 6 Selection Process & Performance Parameters before Machining to be carried out from Literature Survey & Calculation of Performance parameters with the observation of selected process parameters</u>

Selected Process Parameters: Cutting environment, Cutting Fluid Grade, Cutting Fluid Flow rate, Speed rate, Feed rate, Depth of Cut, Diameter (Actual & Measured), Specimen Wear, Length.

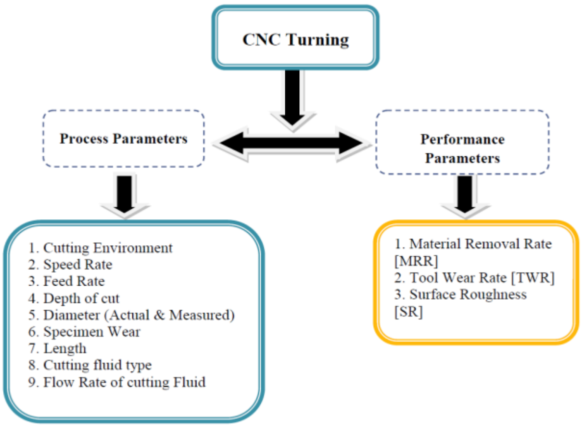


Fig7.CNC Turning Parameters –Process versus Performance

Performance Parameters:

For Surface Roughness Calculation
Instrument Used: SURF-4, Least Count 0.0004 micrometer

Surface roughness tests were conducted on all the samples, produced after each of the 9 trials. Inspection performed at the laboratory of Research & Development centre for bicycle & sewing machine, Ludhiana by using the surface roughness tester made by Mitutoyo Company, Germany can measure a Value up to 100μm.

For Tool Wear Rate [TWR], Material Removal Rate [MMR] Calculation

Instrument Used: Electronic Weight Machine [For Tool Weight Actual & Measured for TWR & For Specimen Weight Actual & Measured for MMR].

Referred Density Table, Mathematically Expression & Geometrical Calculation is also being carried out for calculation of MMR, TWR & compares the performance.

Step 7 Optimization of Performance Parameters Using Empirical Approach

For Optimization of Surface Roughness Parameter

Four process parameters are selected for optimization: Speed rate, Feed Rate, Depth of Cut & Specimen Wear.
Tool Used: Minitab Statistical 16 (30-Days Trial Version) Software [For Taguchi Design & Analysis]

For Optimization of Tool Wear Rate [TWR], Material Removal Rate [MMR] Parameter
Tool Used: MS-Excel [Graphical Method]

Results & Discussion

4.1 Composition Testing of EN-24

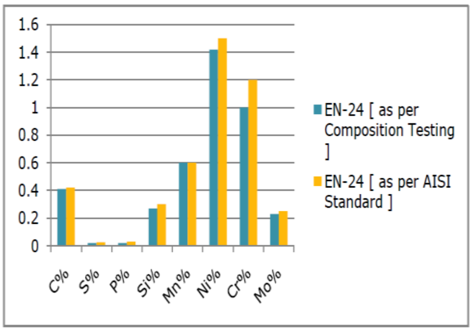


Fig8. Comparison of Composition of EN-24 used as a specimen with AISI Standard Composition

Conclusion: In Comparison All the values Match-able as per AISI Standard .Shows the originality of Material used for testing leads to validity of performances outcomes that carried out further.

Fig9. Pictorial view of machining of workpiece EN-24 on CNC Machine

Cutting Fluid Grade used: No-68 Soluble Oil & Flow rates can be as low as 10 Liter/min for turning

The Use of Cutting Fluids in Turning Operations:

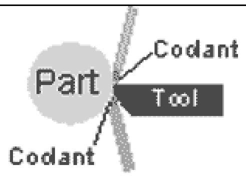


Fig10. For heavy cutting, it is advisable to have cutting fluid directed at the top and bottom of the cutting area.

In a turning operation, the coolant must be supplied to the area where the chip is being produced. For turning and facing operations, the nozzle should be directed so that the coolant is supplied directly over the tool.

Table 4 Cutting Tool Machining Parameters for CNC Turning for Tool Steel i.e. EN-24.

Parameters		A- Rhombus Geometry [Coated, TiN Finished] CNMG			B- Rhombus Geometry [Uncoated] CNMG			C- Triangular Geometry [Uncoated]TNMG		
		Step-1	Step-2	Step-3	Step-1	Step-2	Step-3	Step-1	Step-2	Step-3
Cutting environment		Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet	Wet
Speed Rate , rpm		1800	1800	1800	1800	1800	1800	1800	1800	1800
Feed Rate ,mm/min		0.25	0.2	0.15	0.25	0.2	0.15	0.25	0.2	0.15
Depth of Cut ,mm		1	1	1	1	1	1	1	1	1
Surface Roughness , R_a , µm		0.67	0.35	0.8	0.64	0.63	0.81	43.5	0.63	0.63
Diameter ,mm	Actual ,mm	27	37	47	27	37	47	28	38	48
	Measured , mm	27.16	37.16	47.12	27.13	37.07	47.15	28.8	38.88	48.74
Specimen Wear , µ		160	160	120	130	70	150	800	880	740
Length ,mm		25	25	22	25	25	22	25	25	22

*1 millimeter = 1000 micron

Fig11. Overview of three finished specimens of EN-24 as per dimensions desired using three different tool inserts on CNC machine.

4.2 Performance Parameters

Table 5 Surface Roughness of three different geometry of tool inserts

Processing Step	Surface Roughness of Rhombus Geometry [Coated, TiN Finished] CNMG	Surface Roughness of Rhombus Geometry [Uncoated] CNMG	Surface Roughness of Triangular Geometry [Uncoated]TNMG
Step1	0.67	0.64	0.43
Step2	0.35	0.63	0.63
Step3	0.8	0.81	0.63

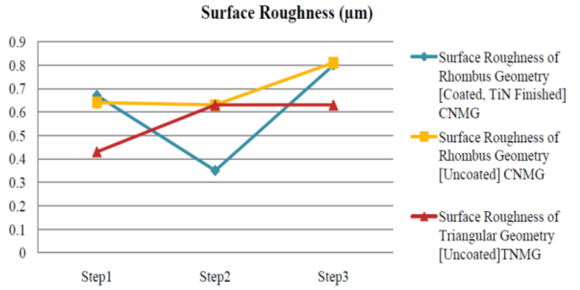


Fig12. Surface Roughness comparison of three different geometry

Table 6 Calculation of Tool Wear Rate TWR (mm^3/min) of three different geometry of tool inserts

Tool Inserts	Tool Wear Rate TWR (mm3 /min)
A- Rhombus Geometry [Coated, TiN Finished] CNMG	0.000314
B- Rhombus Geometry [Uncoated] CNMG	0.000314
C- Triangular Geometry [Uncoated]TNMG	0.00011977

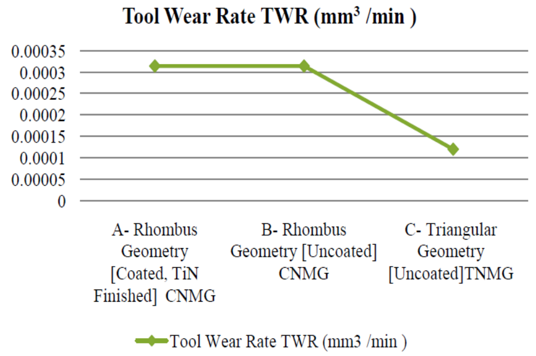


Fig13. Tool Wear Rate TWR (mm^3/min) comparison of three different geometry

Table 7 Calculation of Material Removal Rate MMR (mm^3/min) of three different geometry of tool inserts

Tool Inserts	Material Removal Rate MMR (mm3 /min)
A- Rhombus Geometry [Coated, TiN Finished] CNMG	1879286.6
B- Rhombus Geometry [Uncoated] CNMG	2057613.1
C- Triangular Geometry [Uncoated]TNMG	2057613.1

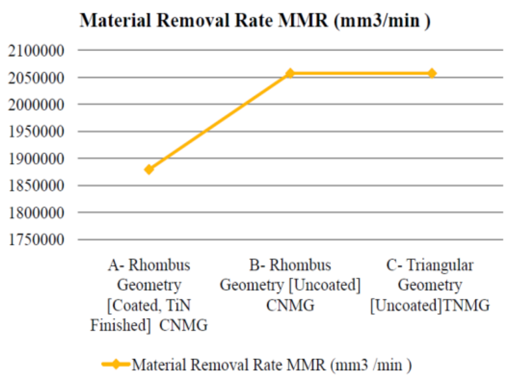


Fig14 Material Removal Rate MMR (mm^3/min) comparison of three different geometry

4.3 Taguchi Design & Analysis Steps

An experimental design methodology that allows you to choose a product or process that performs more consistently in the operating environment. By using Minitab Statistical 16 (30-Days Trial Version) Software.

4.3.1 Design of Experiment [DOE]

Step 1 Create Taguchi Design

Stat - DOE –Taguchi – Create Taguchi Design

Taguchi Design: Taguchi designs use orthogonal arrays, which estimate the effects of factors on the response mean and variation. Orthogonal arrays allow you to investigate each effect independently from the others and may reduce the time and cost associated with the experiment when fractionated designed are used.

Taguchi Orthogonal Array Design
L9(3**4)

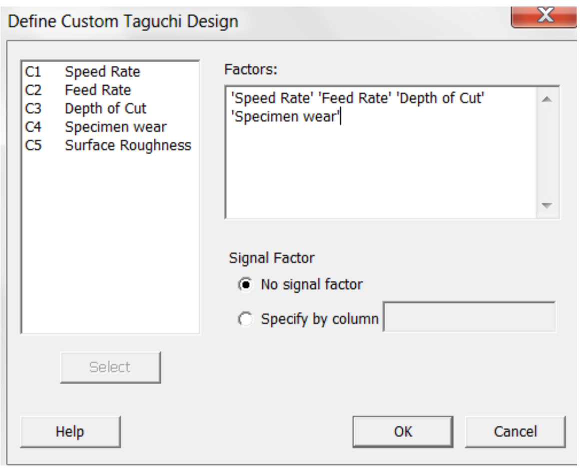
Factors: 4 , Runs: 9

Columns of L9(3**4) Array

1 2 3 4

Step 2 Define Custom Taguchi Design

All these four Process parameters were varied at three levels C1, C2, C3, and C4
Response Variable – C5



Step 3 Analyze Taguchi Design

Table 8 Taguchi Design analysis for Response Variable

Numbers of Trails	Speed Rate	Feed Rate	Depth of Cut	Specimen wear	Surface Roughness
1	1800	0.25	1	160	0.67
2	1800	0.2	1	160	0.35
3	1800	0.15	1	120	0.8
4	1800	0.25	1	130	0.64
5	1800	0.2	1	70	0.63
6	1800	0.15	1	150	0.81
7	1800	0.25	1	800	0.43
8	1800	0.2	1	880	0.63
9	1800	0.15	1	740	0.62

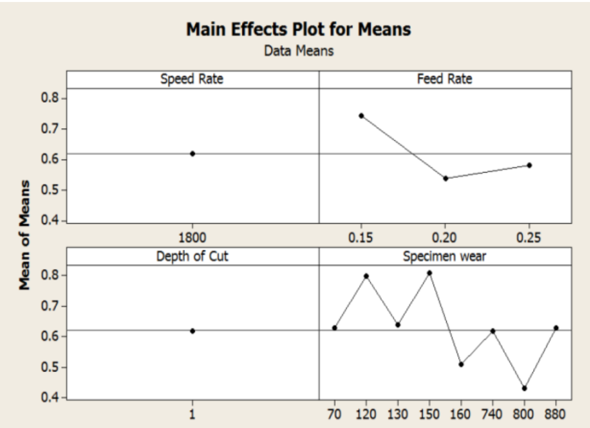
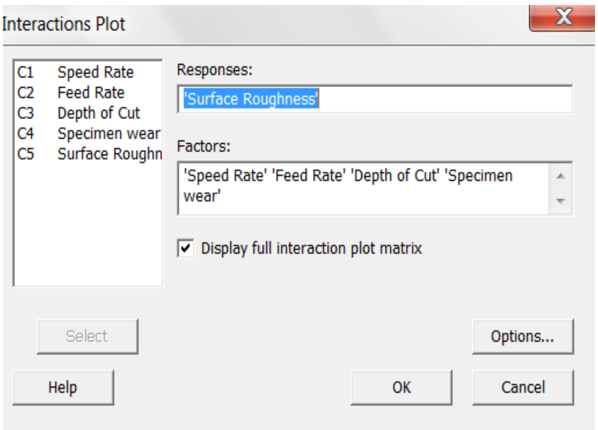


Fig15. Main Effects Plot for Means of Process Parameters for Response Variable



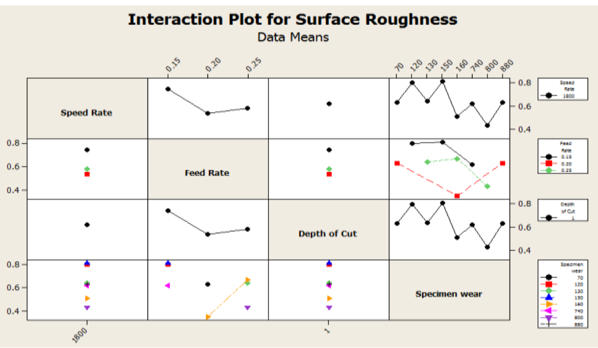


Fig16. Interaction Plot for Response Variable i.e. Surface Roughness

For this experimental work, the response characteristics have been studied as under:

Table 9 Response Characteristics

Response name	Response type	Units
Material Removal Rate (MRR)	Higher the better	mm^3/min
Tool Wear Rate (TWR)	Lower the better	mm^3/min
Surface Roughness	Lower the better	Microns

5. Conclusion of Study

Conclusion for Surface Roughness

In the first step of step turning the roughness value for TNMG is least, showing the optimal value. In second step of step turning we observed that the roughness value for coated CNMG is least indicating optimal value. In third step of turning the roughness value of TNMG is least and constant from the second step. Hence giving the optimum value for surface roughness. Thus from above observation, we conclude that the optimality of TNMG is acceptable reason being the constancy from step2 , as well as lesser that Ra value of uncoated and coated step3 (turning).

Conclusion for TWR

On comparing the calculated values of TWR for three different grades of tungsten carbide tool, we observed that TNMG (triangular) has the least value of TWR, which fulfill the conditions. As we know lesser is the TWR more is the optimality of tool. Hence, it proves that TNMG gives most optimum value which is obtained from the experimental as well as calculation work.

Conclusion of MRR

On comparing the calculated values of MRR for three specimen of same material (EN-24) machined with different grades of tool, we observed that specimen B (uncoated), C (TNMG) has the maximum value of MRR which fulfill the condition. More is the MRR; more is the optimality of work specimen. Hence, it proves that specimen B and C gives the most optimum value which is obtained from the experimental and calculation work. From the above results, we declared that overall optimality of TNMG tool is more as compare to the other grades of tool taken for the experiment. So, we prefer specimen C for MRR value which is being machined with TNMG tool giving the optimal value of MRR.

Most defects in turning are inaccuracies in a feature's dimensions or surface roughness. There are several possible causes for these defects, including the following:

Incorrect Cutting Parameters - If the cutting parameters such as the feed rate, spindle speed, or depth of cut are too high, the surface of the work piece will be rougher than desired and may contain scratch marks or even burn marks. Also, a large depth of cut may result in vibration of the tool and cause inaccuracies in the cut.

Dull Cutting Tool - As a tool is used, the sharp edge will wear down and become dull. A dull tool is less capable of making precision cuts.

Unsecured Work piece - If the work piece is not securely clamped in the fixture, the friction of turning may cause it to shift and alter the desired cuts.

5.1 Process Cycle

The time required to produce a given quantity of parts includes the initial setup time and the cycle time for each part. The setup time is composed of the time to setup the turning machine, plan the tool movements (whether performed manually or by machine), and install the fixture device into the turning machine. The cycle time can be divided into the following four times:

Load/Unload time - The time required to load the work piece into the turning machine and secure it to the fixture, as well as the time to unload the finished part. The load time can depend on the size, weight, and complexity of the work piece, as well as the type of fixture.

Cut time - The time required for the cutting tool to make all the necessary cuts in the work piece for each operation. The cut time for any given operation is calculated by dividing the total cut length for that operation by the feed rate, which is the speed of the tool relative to the work piece.

Idle time - Also referred to as non-productive time, this is the time required for any tasks that occur during the process cycle that do not engage the work piece and therefore remove material. This idle time includes the tool approaching and retracting from the work piece, tool movements between features, adjusting machine settings, and changing tools.

Tool replacement time - The time required to replace a tool that has exceeded its lifetime and therefore become to worn to cut effectively. This time is typically not performed in every cycle, but rather only after the lifetime of the tool has been reached.

In determining the cycle time, the tool replacement time is adjusted for the production of a single part by multiplying by the frequency of a tool replacement, which is the cut time divided by the tool lifetime.

Following the turning process cycle, there is no post processing that is required. However, secondary processes may be used to improve the surface finish of the part if it is required.

The scrap material, in the form of small material chips cut from the work piece, is propelled away from the work piece by the motion of the cutting tool and the spraying of lubricant. Therefore, no process cycle step is required to remove the scrap material, which can be collected and discarded after the production.

5.2 Cost Drivers

Material cost: The material cost is determined by the quantity of material stock that is required and the unit price of that stock. The amount of stock is determined by the work piece size, stock size, method of cutting the stock, and the production quantity. The unit price of the material stock is affected by the material and the work piece shape. Also, any cost attributed to cutting the work pieces from the stock also contributes to the total material cost.

Production cost: The production cost is a result of the total production time and the hourly rate. The production time includes the setup time, load time, cut time, idle time, and tool replacement time. Decreasing any of these time components will reduce cost. The setup time and load time are dependent upon the skill of the operator. The cut time, however, is dependent upon many factors that affect the cut length and feed rate. The cut length can be shortened by optimizing the number of operations that are required and reducing the feature size if possible. The feed rate is affected by the operation type, work piece material, tool material, tool size, and various cutting parameters such as the radial depth of cut. Lastly, the tool replacement time is a direct result of the number of tool replacements which is discussed regarding the tooling cost.

Tooling cost: The tooling cost for machining is determined by the total number of cutting tools required and the unit price for each tool. The quantity of tools depends upon the number of unique tools required by the various operations to be performed and the amount of wear that each of those tools experience. If the tool wear exceeds the lifetime of a tool, then a replacement tool must be purchased. The lifetime of a tool is dependent upon the tool material, cutting parameters such as cutting speed, and the total cut time. The unit price of a tool is affected by the tool type, size, and material.

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Biographies

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