Estimation of Ceramic Tool Insert Life and Surface Finish While Machining SS304 Stainless Steel

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***Abstract*: The challenge of modern machining industries is mainly focused on the achievement of high quality, in terms of workpiece dimensional accuracy, surface finish, and high production rate, less wear on the cutting tools, the economy of machining and performance of the product with reduced environmental impact. At the outset, in several manufacturing industries, the quality of the components plays a significant role in satisfying the engineering needs. Precision and accuracy of components can be attained only by machining with appropriate machine tools and machining conditions. In Engineering, steels are majorly used in automotive, aerospace, and other industrial applications. Many factors affect the surface roughness and tool wear i.e. cutting conditions, tool variables, and workpiece variables. Cutting conditions include speed, feed, and depth of cut, and also tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle, etc. And workpiece variables include the hardness of material and mechanical properties. In the present work ANOVA software is used to estimate the parameters which influence the tool life and surface roughness. The input parameters were Spindle speed (450, 710, 1800 rpm), Feed rate (0.05, 0.063, 0.1 mm/rev), Depth of cut (0.5, 1.0, 1.5 mm) and the response variables were the Surface roughness and tool wear and the effect of Speed, Feed and Depth of Cut on surface finish of Work Piece is studied for the machined surface.**

***Keywords*: Depth of Cut, Speed, Feed, Surface Roughness, SS304 Stainless Steel and Tool Inserts.**

1. INTRODUCTION

Ceramics tool inserts own so many excellent properties like high thermo stability, high wear resistance, and high corrosion resistance that they have become one of the most important tools insert materials. They can withstand higher temperature about 22040C which will allow the softening of work material there by deeper and cleaner cuts can be obtained. Ceramics tools are made by powder metallurgy technique form aluminium oxide (Al2O3) or silicon nitride compounds mixed with additives like titanium oxide and magnesium oxide to improve cutting properties. The primary benefits of ceramic materials for manufacturing tools include high hardness, ability to maintain their properties at extremely high temperature, high electrical and wear resistance, and chemical inertness. Ceramic tools are stable at extreme temperatures as high as 22040 C, unlike carbide and cement tools that contain metallic binders and begin to soften at temperatures greater than 5370 C.

SS 304 has numerous commercial applications in biomedical, marine, automobile, precision manufacturing and chemical processing industries due to its eco-friendliness, excellent corrosion resistance, biocompatibility, and good recrystallization properties. In order to manufacture parts and components to be used in the above mentioned applications, SS has to undergo extensive machining operations. Conventional machining of SS is challenging due to its high work-hardening, low thermal conductivity and high toughness properties.

Inserts are removable cutting tips, which means they are not brazed or welded to the tool body. They are usually indexable, meaning that they can be exchanged, and often also rotated or flipped, without disturbing the overall geometry of the tool. This saves time in manufacturing by allowing fresh cutting edges to be presented periodically without the need for tool grinding, setup changes.

Cutting tools play a very important role in the manufacturing industry as they would determine the quality of a finished product. The performance of a cutting tool directly affects a machines' productivity if they are attached to a cutting machine. Manufacturers take into consideration several factors that concern the effectiveness of cutting tools before purchasing cutting tools for their machining systems. Some of these factors can be that the tool has to have the ability to withstand rigorous operating conditions, perform at very high speeds, resist wear and tear, and it should not deform while in operation. As demands for better cutting tools increase, manufacturers of cutting tools continuously reinvent and develop their products to surpass the expectations of their customers.

Surface roughness most commonly refers to the variations in the height of the surface relative to a reference plane. It is measured either along with a single line profile or along with a set of parallel line profiles (surface maps). It is usually characterized by one of the two statistical height descriptors advocated by the American National Standards Institute (ANSI) and the International Standardization Organization (ISO). These are (1) Ra, CLA (center-line average), or AA (arithmetic average) and (2) the standard deviation or variance (σ), Rq, or root mean square (RMS). Two other statistical height descriptors are skewness (Sk) and kurtosis (K); these are rarely used. Another measure of surface roughness is an extreme-value height descriptor Rt (or Ry, Rmax, or maximum peak-to-valley height or simply P–V distance). Four other extreme-value height descriptors in limited use, are Rp (maximum peak height, maximum peak-to-mean height or simply P–M distance), Rv(maximum valley depth or mean-to-lowest valley height), Rz (average peak-to-valley height), and Rpm (average peak-to-mean height).

There are two methods used for measuring surface roughness. 1. Surface inspection by comparison method e.g., tough inspection, visual inspection, scratch inspection, microscopic inspection, visual inspection, surface photography, reflected light intensity, etc. 2. Direct instrument method e.g., light section method, Forster surface roughness tester, Profilograph, Tomlinson surface roughness meter, Telysurf, etc. Aluminium is used as a matrix material because of its attractive characteristics and second most available material.

2. LITERATURE SURVEY

Neeraja Sharma et al [1] studied on Influence of coated and uncoated carbide tools on tool wear and surface quality during dry machining of stainless steel 304. The study concludes that Carbide tools coated with TiAlN/TiN alternate layers outperformed uncoated tools with a significant reduction in tool flank wear and mean roughness depth (Rz). Approximately 25% reduction in tool wear and 15% reduction in Rz was observed using the coated tool than the uncoated tool. Tool life has been improved by approximately 200% after using coated tools.R.

Perumal et al [2] performed experiments on two materials AISI 304 & AISI 306 Stainless Steel by using Titanium Carbonitride coated tool during CNC Turning and determined the optimum cutting parameters viz cutting speed, feed rate, and depth of cut to obtain better Surface Finish by using Taguchi Method & S/N ratio was calculated. It was found that for both types of materials the optimum cutting speed was 1200 RPM, feed rate of 0.1 mm/rev, and 0.4 mm depth of cut. It was also observed that surface finish is directly proportional to speed and inversely proportional to feed and depth of cut.

Manish Chaudhari et al [3] influence of process parameters such as spindle rotation, feed, and different coating on output parameters such as MRR, surface roughness, tool nose wear, and forces are analyzed. It is observed that the AlCrN and TiN give better surface roughness values (0.48µm) at high spindle rotation (1500rpm) with a low feed rate (0.1mm/rev). The uncoated insert Loses the surface roughness value at a higher feed rate i.e. 0.15 and 0.2 mm/rev. It observed that the nose wear is more at low spindle rotation. As the nose wear increases it leads to the poor dimensional accuracy of the workpiece and the roughness value increases.

S. Palanisamy et al [4] Turning trials were conducted on an ASTM Grade 5 titanium workpiece using diamond-like carbon (DLC) coated tools and the results were compared with machining experiments performed using uncoated carbide cutting tools. The coated cutting tools showed shorter tool life compared to the uncoated tools.

Basmaci [5] has worked on optimization of process parameters like feed rate, depth of cut, and cooling system in turning of AISI 316L stainless steel using Taguchi method. Taguchi's L9 orthogonal array is used to formulate the experiment layout. Cutting forces and surface roughness were measured by using the Carbide tool material. With the help of Pareto's chart, it was determined that depth of cut and feed rate affect the cutting force is most. The best results with the lowest values of cutting force are were obtained by keeping the feed rate 0-1 mm/rev, depth of cut 0-5 mm, and dry cooling system.

3. EXPERIMENTAL SET UPS & METHODS

Automated all geared head lathe: In the Mechanical Engineering field Lathe machine plays an important role in Manufacturing. The machine tool that is used to remove unwanted metals from the workpiece to give the desired shape and size is called a "Lathe machine". Lathe machine is also known as"Centre Lathe" because of two centers between which the job can be held and rotated. Lathe machine is one of the most important machine tools which is used in the metalworking industry. It operates on the principle of a rotating workpiece and a fixed cutting tool. The cutting tool is feed into the workpiece which rotates about its axis causing the workpiece to form the desired shape. He is also known as the father of the entire tool family. It was invented by DAVID WILKINSON (05 Jan. 1771 – 03 Feb. 1852) function of the Lathe machine is to remove excess material in the form of chips by rotating the workpiece against a stationary cutting tool.

Figure 1: Automated all geared head lathe.

Tool Insert: The tool insert used is CCMT 09T304 having the specification of C (Insert shape): Rhombic 800, C (Relief angle): 70, M: Tolerance class, T (Chip breaker and clamping system): Rounded, 09 (Cutting edge): 0.9mm, T3 (Insert thickness): 3.97mm and 04 (Nose radius): 0.4mm.

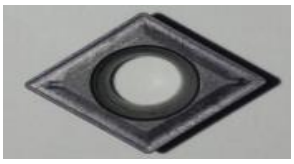

Figure 2: Tool Insert Used.

Material: Stainless steel 304 contains both chromium (between 18% and 20%) and nickel (between 8% and 10.5%) metals as the main non-iron constituents. SS 304 has numerous commercial applications in biomedical, marine, automobile, precision manufacturing, and chemical processing industries due to its Eco-friendliness, excellent corrosion resistance, biocompatibility, and good recrystallization properties.

MINITAB 19: Minitab is a statistics package developed at the Pennsylvania State University by researchers Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner in 1972. It began as a light version of OMNITAB, a statistical analysis program by NIST; the documentation for OMNITAB was published in 1986, and there has been no significant development since then.

Minitab is distributed by Minitab Inc, a privately owned company headquartered in State College, Pennsylvania. Minitab Inc. also produces Quality Trainer and Quality Companion, which can be used in conjunction with Minitab: the first being and Learning package that teaches statistical tools and concepts in the context of quality improvement, while the second is a tool for managing Six Sigma and Lean Manufacturing.

Minitab is a computer program designed to perform basic and advanced statistical functions. It combines the user-friendliness of Microsoft Excel with the ability to perform complex statistical analyses. The Figure shows the MINITAB worksheet with the Taguchi design selected for the design. MINITAB was the most popular statistics package in use in the social sciences. It was first used in teaching and research although some users regarded it as a more limited research tool. No one found MINITAB difficult to use.

Surfcom FLEX 50-A: Surfcom FLEX 50-A is a compact, hand-held surface tester; there is no easier way of measuring, evaluating, and documenting surface roughness. Surfcom flex 50-A measures not only flat, horizontal but also vertical, overhead surfaces and simple measurement to waviness. In addition, 30 complete data records can be stored in the built-in memory and recalled at any time additionally USB memory can be connected in Surfcom FLEX to save more data and a Mini USB connector is equipped with Surfcom FLEX and able to connect with PC. The data can be sent to PC and various analysis is available with ACCTee software. It can measure roughness average (Ra), an average maximum height of the profile (Rz), and maximum roughness depth (Rmax), etc., Table 5.6 gives the technical specification of Surfcom FLEX 50-A meter. It is easy to carry by compact design, it can be used anywhere, it has a built-in printer so we can take the print out directly just by inserting the print paper.

Figure 3: Surfcom FLEX 50-Aused for Measuring surface roughness.

Profile projector: An optical comparator (often called just a comparator in context) or profile projector is a device that applies the principles of optics to the inspection of manufactured parts. In a comparator, the magnified profile of a part is projected upon the screen, and the dimensions and geometry of the part are measured against prescribed limits. It is a useful item in a small parts machine shop or production line for the quality control inspection team.

The projector magnifies the profile of the specimen and displays this on the built-in projection screen. On this screen, there is typically a grid that can be rotated 360 degrees so the X-Y axis of the screen can be aligned with a straight edge of the machined part to examine or measure. This projection screen displays the profile of the specimen and is magnified for better ease of calculating linear measurements. An edge of the specimen to examine may be lined up with the grid on the screen. From there, simple measurements may be taken for distances to other points. This is being done on a magnified profile of the specimen. It can be simpler as well as reduce errors by measuring on the magnified projection screen of a profile projector.

Figure 4: Profile projector

Methodology Followed:

- Constructing the Taguchi Table according to L9 Orthogonal Array.
- Conducting the experiments by using the Taguchi Table in the Automated All Geared Head Lathe for the Turning Operation.
- After machining the SS 304 work material, its surface roughness is measured using the Surfcom Flex.

- Tool wear is measured by using a metallurgical microscope.
- Optimization of cutting parameters to get a high surface finish by using the Taguchi technique and ANOVA.
- Comparison between coated and uncoated ceramic tool inserts.

4. RESULTS & DISCUSSIONS

The optimizations of process parameters are usually performed as per the traditional Taguchi approach using a signal-to-noise ratio. A higher signal-to-noise ratio means closer to optimal process parameters. It can optimize the response and able to optimize the number of responses. The experimental design matrix based on the Taguchi L9 orthogonal array technique and corresponding values of responses is shown in Table 1 shown below. Two main machinability indicators that are surface roughness and tool wear have been considered as the major responses in the present work.

Parameters	**Level 1**	**Level 2**	**Level 3**
Spindle speed (rpm)	450	710	1800
Feed rate (mm/rev.)	0.05	0.063	0.1
Depth of cut (mm)	0.5	1.0	1.5

Taguchi Analysis: Table 2 below shows theSurface roughness in Microns on turning SS 304 using Ceramic CCMT 09T304tool inserts:

Level	**Spindle Speed**	**Feed Rate**	**Depth of Cut**
1	2.0312	3.4432	0.9130
2	2.6466	1.0431	2.0264
3	2.1471	1.9556	0.4086
Delta	4.7937	5.3988	2.4350
Rank	2	1	3

According to Taguchi analysis, the most predominant factors for surface roughness on machining SS 304 for tool insert are feed followed by speed and the least influential factor is DOC as shown in Table2. It shows that surface roughness depth increased with the feed rate. Significant feed marks are sustained with a high feed rate and also built-up edge is prominent and therefore surface quality with finish deteriorated. It is found that an increase in cutting speed decreases surface roughness. High cutting speed favors the surface quality as the build-up edge vanishes. In other words, due to low build-up edge formation at high cutting speeds, the surface finish improves. At low cutting speed, the chip fracture took place very rapidly that deteriorates surface quality. An increase in DOC increased mean roughness depth. At the high depth of cut, a significant amount of tool and work material remain in contact and due to generation of high cutting temperature, while machining at high DOC, transfer of wok material to tool and vice-versa along with inhibition of heat due to low thermal conductivity of SS304 deteriorated work surface finish and quality.

Signal to Noise Ratio for uncoated tool inserts:

For uncoated tool inserts, the most predominant factor of tool wear is speed followed by feed and DOC as shown in Table 3.

Level	**Spindle Speed**	**Feed Rate**	**Depth of Cut**
1	-18.71	-29.04	-16.70
2	-20.58	-20.00	-26.00
3	-29.22	-19.47	-25.81
Delta	10.52	9.57	9.29
Rank	1	2	3

It has been observed that with the increase of cutting speed, feed, and depth of cut (DOC) the tool wear also increases. The tool wear increases because of the high friction at the chip-tool interface. With the increase in the speed, the chip travels the flank face at a high speed hence the surface morphology of the tool insert reveals a non-uniform surface roughness. So, the movement of the chip on an tool inserts develops a high coefficient of friction hence it generates a higher temperature as compared to a smooth surface (due to low coefficient of friction at coated tool). This higher temperature in the chip-tool interface facilitated the plastic deformation of the work material and the harder particles like nitrides, oxides eroded some tool material. This increased the tool wear for tool inserts materials.

Surface roughness versus spindle speed, feed rate, DOC:

Figure 5 represents the main effect plot for surface roughness and it indicates the optimal machining parameters speed=450 rpm, feed rate=0.063 mm/rev, depth of cut=1.5 mm.

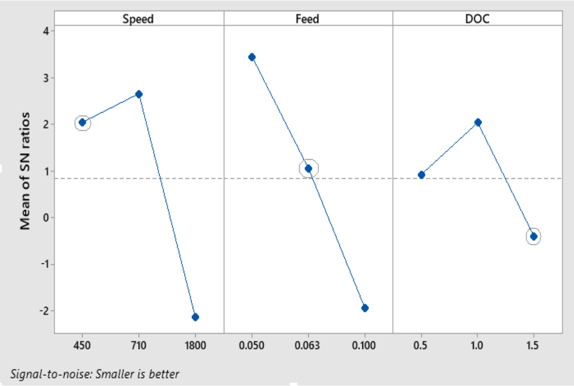

Figure 5: Surface roughness versus spindle speed, feed rate, DOC.

Tool wear versus spindle speed, feed rate, DOC: Figure 6. represents the main effect plot for tool wear and it indicates the optimal machining parameters speed=450 rpm, feed rate=0.1 mm/rev, depth of cut=0.5 mm.

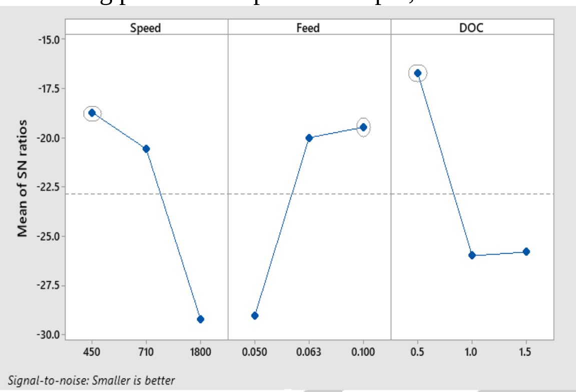

Figure 6.2: Tool wear versus spindle speed, feed rate, DOC.

5. CONCLUSIONS

i. The present study is concerned with the turning of Stainless Steel 304 (SS304) by using the Taguchi technique and ANOVA to optimize the surface roughness and tool wear. The machine used to conduct the experiment was an Automated all geared head lathe. The experiments were performed based on L9 Orthogonal Arrays.

ii. The input parameters were Spindle speed (450, 710, 1800 rpm), Feed rate (0.05, 0.063, 0.1 mm/rev), Depth of cut (0.5, 1.0, 1.5 mm) and the response variables were the Surface roughness and tool wear. After the experiments were conducted, the response variables were tabulated and analysis was conducted.

iii. The most affecting parameters among the three cutting parameters i.e., spindle speed, feed rate and depth of cut for the surface roughness, the most significant factor is the depth of cut followed by the spindle speed and the least significant is the feed rate. For the tool wear, the most significant factor is spindle speed, followed by the depth of cut and the least significant is the feed rate.

iv. Optimized cutting parameters for surface roughness are speed=710 rpm, feed rate=0.1 mm/rev, depth of cut=0.5 mm and optimized cutting parameters for tool wear are speed=710 rpm, feed rate=0.063 mm/rev, depth of cut=1.0 mm.

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