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Assessment of the Effect of Titanium Nitride Coating on Ceramic Tool Insert and Estimation of Tool Life and Surface Finish While Machining SS304 Stainless Steel

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Abstract -Modern machining industries are primarily concerned with achieving high quality in terms of workpiece dimensional precision, surface finish, and high production rate, as well as reducing cutting tool wear, machining economy, and product performance while reducing environmental effect. To begin with, in various manufacturing industries, component quality plays a critical part in meeting technical requirements. Only machining with appropriate machine tools and machining conditions may achieve component precision and accuracy.Steels are widely employed in engineering applications such as automotive, aerospace, and other industrial uses. The tool Wear and Surface Roughness are influenced by Cutting parameters like speed, feed, and cut depth.To improve the tool life, inserts were coated with harder materials to achieve better performance. Coated tool inserts increase the tool life by increasing toughness, resistance to abrasion, resistance to thermal deformations, modulus of elasticity, and wear resistance, which results in achieving precision and accuracy in machining components. Also, these coated tool inserts broaden the range of depth of cut, cutting speed, other machining parameters and reduce the time of machining. Coating of tool Inserts gives longer tool life, higher cutting parameters leading to reliable performance while machining.The ANOVA software is used to estimate the characteristics that influence tool life and surface roughness in this study. The response variables were Surface roughness and tool wear, and the input parameters were Spindle speed (450, 710, 1800 rpm), Feed rate (0.05, 0.063, 0.1 mm/rev), and Depth of cut (0.5, 1.0, 1.5 mm). The effect of Speed, Feed, and Depth of Cut on surface finish along with tool life for Work Piece is studied for the machined surface.

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

1. INTRODUCTION

Ceramic tool inserts have become one of the most essential tool insert materials due to their great qualities such as high thermal stability, high wear resistance, and high corrosion resistance. They can endure greater temperatures of around 2204^{0}C, which allows the work material to soften, allowing for deeper and cleaner cuts. To increase cutting qualities, ceramic tools are manufactured using a powder metallurgy approach using aluminium oxide (Al_2O_3) or silicon nitride compounds combined with additions such as titanium oxide and magnesium oxide. High hardness and the ability to maintain characteristics at extremely high temperatures are the fundamental advantages of ceramic materials for tool insert manufacturing.

Because of superior corrosion resistance, eco-friendliness, biocompatibility, and outstanding recrystallization qualities, SS 304 has a wide range of commercial applications in the biomedical, marine, vehicle, precision manufacturing, and chemical processing industries. SS must undergo significant machining procedures in order to make parts and components for the above-mentioned applications. Because of its strong work-hardening, low thermal conductivity, and high toughness, conventional machining of SS is difficult.

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 plays asignificantpart in the manufacturing industry as they would control the quality of a final 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.

Tool Inserts were coated with tougher materials to increase tool life and to improve the overall performance. Coated tool inserts extend tool life by improving toughness, abrasion resistance, thermal deformation resistance, modulus of elasticity, and wear resistance, allowing for greater precision and accuracy while cutting components. These coated tool inserts also increase the wide range of depth of cut, cutting speed, and other machining parameters while reducing machining time. Tool insert coating extends tool life and increases cutting parameters, resulting in consistent machining performance when compared with uncoated tool inserts.

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 the 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.

S.Ganeshkumar et al [2]conducted the research work, while machining the EN8 Material with silicon carbide tool inserts and Titanium nitride coated tool inserts. The wear rate of the inserts was measured using a toolmakers microscope, and the flank wear and crater wear was considered for the tool wear measurement. The results showed that the uncoated tool inserts will have the lesser tool life when compared with Titanium nitride coated tool inserts.

J. Rajaparthiban et al [3]in his experimental study which uses Taguchi design and developed L9 orthogonal array to study the influence of machining parameters on surface roughness and tool wear while machining EN31 steel. From the results obtained from Taguchi design of Experiments and analysis, the cutting speed is the main factor that has the highest influence on Surface roughness as well as tool wear of turning and facing processes.

R. Perumal et al [4] performed experiments on two materials AISI 304 & AISI 306 Stainless Steel by using Titanium Carbo-nitride 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.

Dharindom Sonowal et al [5] in his investigation studied the effect of Spindle speed, Feed, and Depth of Cut andfound the significant parameter which influence the surface roughness while machining AISI 1020 mild Steel. A confirmatory experiment has been also conducted to verify the results predicted from Taguchi optimization. In the confirmatory experiment, the average value of surface roughness is found to be 2.408 µm which is well within the range ($0.418 \leq Ra (CE) \leq 4.299$) predicted for the confirmatory experiment.

Manish Chaudhari et al [6]studied the 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 is 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.

Basmaci [7] has worked on optimization of process parameters like feed rate, depth of cut, and cooling system in turning of AISI 316L stainless steel by 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 most. The best results with the lowest values of cutting force 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.

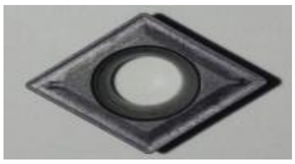

Figure 2: Tool Insert Used.

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 conventional Taguchi approach of applying a signal-to-noise ratio to optimize process parameters is commonly used. A higher signal-to-noise ratio indicates that the process parameters are closer to being ideal. It has the ability to optimize both the response and the amount of responses. Table 1 shows the experimental design matrix based on the Taguchi L9 orthogonal array technique and the accompanying response values. In this study, the key responses were surface roughness and tool wear, which are the two most important machinability parameters.

Table 1: Cutting parameters

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 TiN Coated Ceramic CCMT 09T304tool inserts.

Table 2: Surface Roughness in Microns.

Level	Spindle Speed	Feed Rate	Depth of Cut
1	5.114	4.770	2.721
2	3.779	4.062	5.457
3	3.850	3.910	4.565
Delta	1.335	0.860	2.736
Rank	2	3	1

According to Taguchi analysis, the most predominant factors for surface roughness on machining SS 304 using coated tool insert are DOC followed by speed and the least influential factor is feed as shown in Table 2. After using the coated tool, reduction surface roughness at different cutting speeds has been observed. The surface quality of the machined surface deteriorated more rapidly in the uncoated tool as compared to a coated tool that is low roughness has been obtained in case of turning with coated tools. The low coefficient of friction between the tool chip interfaces due to the presence of coating is the possible reason behind that. It can finally be concluded that improvement in the surface finish has been achieved with coated tools.

Signal to Noise Ratio for coated tool inserts:

For coated tool inserts most predominant factor of tool wear is speed followed by DOC and feed as shown in table 3.

Table:Signal to Noise Ratio for coated tool inserts

Level	Spindle Speed	Feed Rate	Depth of Cut
1	-12.829	-15.720	-13.215
2	-7.195	-13.215	-10.034
3	-24.580	-15.668	-21.354
Delta	17.385	2.504	11.319
Rank	1	3	2

The hard coating of TiN and smooth surface of tool inserts decreased the coefficient of friction at chip tool interface and reduced the erosion of tool material by nitride and oxide of work- materials. Therefore, comparatively low tool wear and its increment with the cutting speed have been observed. Tool wear at high speed is more due to tearing, attrition, and abrasion of the chip on the surface. It has also been observed that at the high value of feed and DOC, the tool edge was severely affected due to the development of high contact pressure and the formation of the build-up edge. The material transfer takes place due to abrasive action where the chips remain in contact with the tool all the time. The insert surface morphology plays a pivotal role in tool wear and material transfer.

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=710 rpm, feed rate=0.1 mm/rev, depth of cut=0.5 mm.

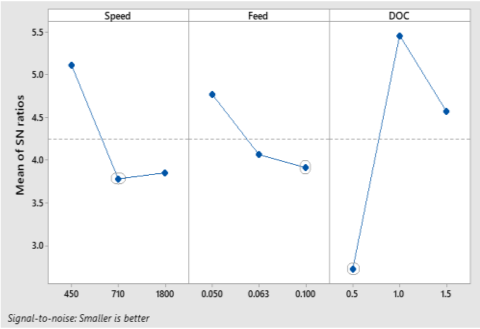

Figure 5: Surface roughness versus spindle speed, feed rate, DOC.

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=710 rpm, feed rate=0.063 mm/rev, depth of cut=1.0 mm.

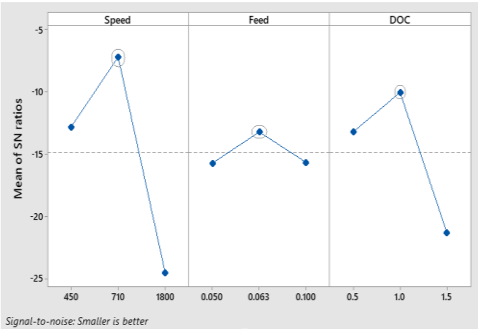

Figure 6: Tool wear versus spindle speed, feed rate, DOC.

5. CONCLUSIONS

i. The present study is concerned with the effect of TiN Coating on Ceramic tool inserts while 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.

v. Comparatively the TiN Coated Tool inserts have the Long Tool Life and Good Surface Finish compared to uncoated Ceramic tool inserts.

REFERENCES

1. Neeraj Sharmaand Kapil Gupta. “Influence of coated and uncoated carbide tools on tool wear and surface quality during dry machining of stainless steel 304”, Materials Research Express, Volume 6, Issue 8.
2. Ganesh Kumar S, Thirunavukkarasu V, Suresh Kumar R, Venkatesh S & Ramakrishnan “Investigation of Wear Behaviour of Silicion Carbide Tool Inserts & Titanium Nitride Coated Tool Inserts in Machining of EN8 Steel”. International Journal of Mechanical Engineering & Technology, Volume 10, Issue 1 PP 1862-1873.
3. Rajaparthiban J, Adhichelvan B, Ananthan, A, Mahesh N & Balaji R, “Experimental Investigation of Cutting Parameters Influence on Tool Wear & Surface Roughness in Turning of EN31 Steel Using Carbide Inserts in CNC Turning Center”. International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181.
4. Nethaji Perumal, Dr. B. Kumargurubaran , Dr. T. Sethil Kumar (2018) “Optimisation of cutting parameters in CNC turning of AISI 304 &AISI 316 Stainless steel, International journal of trend in scientific research and development (IJTSRD) 2 (4) , 955.
5. Dharindom Sonowal, Dhrupad Sarma, Parimal Bakul Barua, Thuleswar Nath, “Taguchi Optimization of Cutting Parameters in Turning AISI1020 MS with M2 HSS Tool”

IOP Conference Series: Materials Science and Engineering.

6. Chaudhari M & Karunamurthy K, "Determining The Effect of Coated and Uncoated Tool Insert During Turning of EN31 Steel" International Journal of Mechanical Engineering and Technology, Volume 8, Issue 11, 2017.
7. Basmaci G "Optimization of Machining Parameters for the Turning Process of AISI 316L Stainless Steel and Taughi Design " Acta Physica Poloncia PP260-264.
8. Palaniswamy S, Rahman Rashid R A, Brandt M & Dargush M S "Tool Life Study on Coated/Uncoated Carbide Inserts Durning Turning of Ti6Al4V" Advanced Materials Research PP136-140.
9. J.A. Ghani , I.A. Choudhury, H.H. Masjuki. "Wear mechanism of TiN coated carbide and uncoated cermets tools at high cutting speed applications", Journal of Materials Processing Technology 153–154 (2004) 1067–1073.