Performance Evaluation of PVD and CVD Multi Coated tool on AISI 304 Austenitic Stainless Steel- a Review

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Abstract

This Paper describes a comprehensive Literature review of major published Research work performed on machining of AISI 304 Austenitic Stainless Steel. Austenitic Stainless Steel have been extensively used all over the World due to its wide spread Application and have demand in the Industry over other Steel families. In modern Machining Processes customer and manufacturers are more concern about the Super finish of the machined product, and cost of the machined product and its aesthetic look. Companies are more concerned about high production rate that is Material removal rate, Surface integrity, low Power consumption etc. This review work encompasses the focus on different coating materials and different coated tools have emerging to improve Surface Integrity, Surface finish, Material Removal rate (MRR), vibration, Wear rate and Temperature Consideration. Based on the literature reviewed further research scope is identified. The present research reveals that there is a further scope to optimize the various process parameters as well as the PVD and CVD coated tool is considered as one of the process parameter and its performance on surface roughness and material removal rate is identified. DOE will be carried out by taguchi method and ANOVA will be used.to find out most influential parameter on output response.

Keywords: *Surface Roughness, Material Removal Rate , AISI 304 machining , CVD, PVD coatings , Coated inserts. Taguchi Method, ANOVA.*

1.INTRODUCTION

The material removal process typically deals with the shearing off the excess material in the form of small chips through mechanical contact between the cutting tool and work piece [1]. The main objective of the metal cutting process is to manufacture the desired geometry and surface finish of the product with tight tolerances, high productivity and reliability, low cost, and good quality. High productivity is very much associated with the cutting parameters, i.e., high values of cutting speed, depth of cut, and feed.[1]. Stainless steels are typically used to manufacture food processing and chemical equipment, as well as machinery parts that require high corrosion resistance. Austenitic Stainless steels are known for their high work hardening rate, low thermal conductivity, high ductility, high tensile strength and high fracture toughness. American Iron and Steel Institute (AISI) 304austenitic stainless steel contains a minimum of 18% chromium to increase the hardness of the steel without compromising its ductility. Chromium content improves the grain refinement in the steel, which also increases its toughness and enhances the high-temperature strength of the steel. Stainless steel 304 also contains a minimum of 8% nickel to improve toughness, especially at low temperatures, reduce corrosion and minimize scratches. Nickel also imparts some heat resistance to the 304 stainless steel [4] As of late, green or dry manufacturing has gained popularity in the manufacturing industry to meet environmental regulations and mitigate occupational health hazards. The major benefit of dry machining is that it leaves behind no atmosphere or water pollution and produces no swarf residue, which reduces associated disposal costs and health issues. In general, dry machining also reduces machining costs. Since now the product produced by CNC is not always acceptable. This may be due to use of non-optimized process parameter for given work piece and cutting tool. Material removal rate (MRR) is considered as output response characteristic since it affect production rate. AISI 304 austenitic stainless steel are turned on CNC lathe by using PVD and CVD coated cemented carbide inserts. It was found that the formulation of cutting parameters has significant influence on cutting quality, production rate, and energy consumption. So there is a need of selection of proper performance parameters and need of optimizing them. By Taguchi, RSM etc. and also there is a need of selection of optimization technique also there is a need of doing analysis with ANOVA, Regression analysis etc.

2. LITERATURE REVIEW:

The following Research work encompasses the Exhaustive research done by Number of researchers in the area of Austenitic stainless Steel. Special attention is on coated cutting Inserts and their influence on various parameters on machining of Austenitic Stainless steel and parametric influence on output factors such as Surface Roughness, Material Removal Rate, Tool wear, Chip Morphology and Economic Power consumption etc. The aim of this paper is to share the exhaustive research work done by various researchers in the area of improving the Machining of AISI 304 Austenitic stainless steel and improving the output parameters by selecting optimum input process parameters. The detailed review related to the specied area is discussed below

Mohammad Bilal Naim Shaikh et. al.[1] They discussed various aspects of conventional cutting fluids. And their application method have been discussed. Which serve different functions such as cooling, lubrication, cleaning, and corrosion protection during the machining process. They discussed on social, economical and environmental aspects of conventional cutting fluids. They necessitated the various alternatives and reviewed thoroughly. They concluded on the need of various sustainable methods such as dry machining cryogenic machining, minimum quantity lubrication and environmental friendly machining .gas based coolants and solid lubricants. Lastly they focused on knowledge of cutting fluid type and their application and challenges.

Mohammad Butt et. al.[2] They addresses the performance of Multi layered PVD and CVD coated inserts in severe dry turning of AISI 4340 steel. They used Taguchi's L9 Orthogonal array. They also applied Analysis of variance to know the optimum influential factor on turning insert. Flank wear and surface Roughness were estimated by optical microscope and surface roughness tester respectively. Their obtained result were reveled that For surface roughness feed rate was found more significant factor followed by Cutting speed, for both PVD and CVD coated carbide tools. Better surface finish was observed on PVD coated insert at low and medium velocities . with increasing velocity CVD coated tools show better surface roughness.They also observed that under higher velocities CVD coated tool shows less wear as compared to PVD coated tool.

Darshit Shah et. al.[3] They conduct an experimental trial on Ti-6Al-4V . Four cutting parameters were chosen by them namely cutting speed, feed, depth of cut and tool nose radius and responses of cutting force, cutting temperature and surface Roughness have been investigated by turning Ti-6Al-4V (ELI). They carried out ANOVA, and total 81 experiment have been performed in dry environment. They also developed mathematical model for cutting force, cutting temperature and Surface Roughness have been developed using Response surface methodology. ANOVA test has been carried out to evaluate contribution of parameters. They obtained minimum surface roughness of 0.328μm at cutting speed of 140 rpm. feed of 0.0510 mm/rev, depth of cut of 0.7mm and nose radius of 1.2 mm. They also carried out confirmation test and found out minimum cutting force of 7 kgf, minimum surface roughness as 0.35μm and cutting temperature of 30 0C.

Uttkarsh S. Patel et. al.[4] This research investigated the wear morphology of a Ti(C,N)-based cermet tools used for the high-speed dry turning of austenitic stainless steel (AISI304) specifically for finishing operation. The goal of the study was to investigate the influence of compositions from different cermet tools supplied by various manufacturers on microstructure, properties and tool wear morphology while finishing turning of AISI 304. Progressive wear study was performed at a fixed cutting length interval to measure the tool wear of different cermet tools. By conducting the experiment they found that different elemental concentrations alter the microstructure of cermet tools by changing its core size and shape, which eventually shows the influence on mechanical properties and machining performance. The study revels that various elements are forming different compositions in cermet tools that play a critical role in determining their binding strength, heat resistance and lubricity during machining, which significantly affects the tool life.

Yu Su, Guoyong Zhao et. al.[5] This paper presents a multi-objective optimization method of cutting parameters based on grey relational analysis and response surface methodology (RSM), which is applied to turn AISI 304 austenitic stainless steel in order to improve cutting quality and production rate while reducing energy consumption. They applied Taguchi method to design the turning experiment and the multi objective optimization problem was converted to a simple objective problem through grey relational analysis. Finally the regression model based on RSM for grey relational grade was developed. and the optimal turning parameters were obtained, namely depth of cut 2.2 mm, feed rate 0.15mm/rev and speed of 90 m/s was obtained. Surface roughness Ra decreases to 66.90% , MRR increases to 8.82% and Specific Energy consumption decreases to 81.46%.

A.N. Aladwani et. al.[6] the Aim of the research work was to investigate the effect of type and coating material of cutting tool on Surface Roughness and Roundness error of turning of AISI 304 Austenitic Stainless Steel. They formulate the experiment by taking cutting speed, feed rate, type of tool coating and depth of cut as process parameters. For experiment Taguchi's L27 array was used also ANOVA is used to analysis the experimental results. Also signal to noise ratio were used to analysis the performance characteristic in turning operation. They observed that the cutting speed is the most significant factor on Surface Roughness followed by tool coating also cutting speed is the most significant factor on MRR followed by depth of cut. Also they observed that cutting speed is the most significant factor on Roundness error followed by type of tool coating.

N.V.S Shankar et. al.[7] The aim of this research was to optimize the process parameters for minimizing the Surface Roughness and vibrations. The process parameters were namely MQL condition, Depth of cut and Spindle speed and response was Surface Roughness and Vibrations. Mixed level optimization was performed by them and Taguchi analysis with L18 orthogonal array was used to optimize the process parameters for minimizing the Surface Roughness and vibration.They turn EN19 with coated carbide insert with conventional Lathe machine, three factors MQL condition ,Depth of cut and spindle Speed. A Taguchi's Mixed Orthogonal array of L18 was used and the considered factors was optimized for Surface Roughness and vibration for minimizing the same

M. Venkata Ramana et. al. [8] Experimented on AISI 321 to Optimized the Process parameters. They did turning on AISI 321 by taking PVD and CVD coated carbide tool. The objective was to Optimized cutting parameters for maximizing Material Removal Rate using Taguchi method. The optimum cutting parameters obtained was cutting speed at 80 m/min, feed rate at 0.2 mm/rev and depth of cut at 1 mm in case of both CVD and PVD coated tool. Material Removal Rate was predicted using regression Model. The influence of cutting parameters on material removal rate was characterized using analysis of variance. 3D surface plots demonstrate the effect of change in cutting parameter on material removal rate. The validation experiments were performed at optimum cutting conditions by them to evaluate effectiveness of the technique.

V. Durga Prasad Rao et. al. [9] They focuses on the fact that coated tool improves certain machining characteristic over uncoated tool. In their research they considered multi objective optimization on Surface Roughness (Ra) and Material Removal Rate (MRR) were considered during turning of stainless steel 304 with uncoated and TiAlN Nano coated carbide tool under dry condition. They used PVD method for Nano coating of TiAlN under Dry condition. The experiment was done under Taguchi Orthogonal Array. Then on the basis of experimental results for Ra and for MRR, the second order regression equations have been developed in terms of machining parameters used. Regarding the effect of machining parameters, an upward trend is observed in Ra with respect to increasing feed rate. Also as the cutting speed increases, Ra value increased slightly due to chatter and vibrations. It is found that the feed rate and depth of cut are the dominant parameters with respect to the MRR. Then to test the adequacy of regression equations of response variables, additional experiments were conducted. The predicted Ra and MRR values of uncoated and coated tools are found to be a close match of their corresponding experimental values.

Umashankar Gupta et. al [10] were investigated that Nickel base super alloys processed by the powder metallurgy (P/M) route exhibit improved mechanical properties due to fine-grain homogeneous microstructure over the conventional wrought alloys. They demonstrated the performance of an uncoated, single layer and multilayer coated carbide tools in high speed turning operation of advanced P/M nickel based super alloy. The tool performance was evaluated in terms of tool wear, surface finish, diametric deviation and micro hardness. And they observed that tool wear was lowest for multilayer coated tool. The decrease in micro hardness value at machined surface was observed with all variants of tools. The surface roughness was higher with uncoated tool and lower with coated tools. The multilayer coated tool found to be most preferred tool for these super alloys in high cutting speed range (up to 150 m/min). The single layer coated tool can be preferred at intermediate speed.

Sudhansu Ranjan Das et. al [11] They focuses on the fact that the newer hardened material that coming in the market, their Machinability is prime concern and need to be investigated prior to actual machining. Their research addresses surface roughness, flank wear and chip morphology during dry hard turning of AISI 4340 steel (49 HRC) using CVD (TiN/TiCN/Al2O3/TiN) multilayer coated carbide tool. Three factors (cutting speed, feed and depth of cut) and three-level factorial experiment designs with Taguchi's L9 Orthogonal array (OA) and statistical analysis of variance (ANOVA) were performed to investigate the consequent effect of chosen cutting parameters on the tool and work piece in terms of flank wear and surface roughness. also wear mechanism of worn coated carbide tool and chip morphology of generated chips were observed by scanning electron microscope (SEM), multiple regression analysis was adopted by them to develop mathematical model for each response, along with various diagnostic tests were performed to check the validity and efficacy of the proposed model. Finally, to justify the economical feasibility of coated carbide tool in hard turning application, a cost analysis was performed by them based on Gilbert's approach by evaluating the tool life under optimized cutting condition. They found that Surface roughness and Flank wear were statistically influenced by feed and cutting speed. Their study revealed that the effectiveness and potential of multilayer TiN/TiCN/Al2O3/TiN coated carbide tool for hard turning process during dry cutting condition possesses high yielding and cost-effective benefit to substitute the traditional grinding operation. Apart, it also contributes reasonable option to costlier CBN and ceramic tools

Kaushik Vijaya Prasad et. al [12] Researchers used Lateral rotating cathodes technology showed that The nc-AlTiN/Si3N4, TiAlN, and TiN coating were deposited using lateral rotating cathodes (LARC) technology on TNMG 160404 cemented carbide turning inserts and ultra fine grade semented substrate were used in the case of TiAlN and TiN inserts. And the grane structure was observed by scanning electron Microscopy. And they conducted dry machining on AISI 304 Austenitic steel. Grey relation analysis was carried out to optimize the machining parameters and they obtained that nc-AlTiN/Si3N4 coating showed the highest hardness of 28 GPa. The coating also shows a dense grain structure. Furthermore, in cutting tests even under severe dry cutting conditions, the wear observed was less than TiAlN and TiN coating and surface finish imparted to work parts was less than 2 μm by this coating. They also found that nc-AlTiN/Si3N4and TiAlN coating provide a good cutting performance over TiN coating.

Nithyanandhan et. al [13] The aim of the research was to optimize process parameters on surface finish and Material Removal Rate (MRR) by using Taguchi's Optimization Method. And analysis of variance (ANOVA) is used to analyze the influence of cutting parameters during machining of AISI 304 stainless Steel. They turned the material on conventional lathe machine by using Tungsten carbide tool. The Experimental result revealed that the feed and nose radius is the most significant process parameters on work piece surface roughness. However, the depth of cut and feed are the significant factors on MRR. Optimal temperature was obtained using the establish wear Model. Taguchi method was applied to optimized the process parameters on tool wear and cutting forces in hard turning of AISI 304 Stainless Steel. Experimentally obtained results revealed that cutting speed and depth of cut have significant effect on feed force whereas feed rate and depth of cut are factors that significantly influences on thrust force. The depth of cut and cutting speed has predominant effect on tool wear. Feed rate have less significant effect on tool wear.

M.S. Ranganath et. al [14] They gave attention on various factors that seriously affect surface Roughness. The various controllable parameters for the CNC machines include cutting tool variables, work piece material variables and cutting conditions etc. They spoke about many techniques are used for optimization of machining parameters include Taguchi RSM and ANOVA approach to determine most significant parameter. Also they discussed other parameters as cutting force and power consumption.

Atul P. Kulkarni et. al [15] Researchers used Quaternary Nitride AlTiCrN coating for dry turning of AISI 304. The coating was deposited using high power pulsed magnetron sputtering on ISO K20 grade cemented carbide insert. and SEM , micro hardness tester and scratch tester were used to examine microstructure, micro hardness and adhesion of coating. The effects of machining parameters on surface finish, cutting force, tool wear chip thickness and tool life were investigated during the Experimentation. Superior surface finish and minimum cutting force were obtained.

Swapnagandha S. Wagh et. al [16] They focuses their research on Environment friendly machining. That is Dry machining. They use cathodic Arc Evaporation Technique (CAE). for
depositing AlCrN/ TiAlN coating used for dry, high speed turning of AISI 304 austenitic stainless steel The effect of machining parameters on the cutting force, cutting temperature and surface finish were investigated during the experimentation. It is found that, as feed increases, the radial force increases therefore more friction exists between

newly generated surface and the flank face so surface roughness increases. Tool-chip interface temperature increases with increase in cutting speed and it is higher because of low thermal conductivity of the coating as well as AISI 304 work material and AlCrN/TiAlN coating. Thermal stability of the AlCrN/TiAlN coating is good therefore it withstands the high temperature and gives better performance especially in case of dry turning and It also helps in reduction in cutting forces.

M. Narasimha et. al [17] This research deals with the ways of improving the tool life by various coatings on tungsten based cemented carbide cutting tool. The coatings like TiN, Al2o3, TiN/Al2 O3, and TiC/ Al2 O3/ TiN respectively are extensively in use. In this review, the machining performance of coated tungsten based cemented carbides, with 550 diamond shape, were investigated during finish turning of AISI 1018 steel under dry conditions. The coatings are of TiN, Al2 O3, TiN/ Al2 O3 and TiCNi/ Al2 O3/TiN respectively. For comparison, uncoated cemented tungsten carbides were also tested under the same cutting conditions. They also found that

The coated tools exhibited superior wear resistance over the uncoated tool. The TiC/ Al2 O3/TiN coated tool had the lowest flank wear .The Al2 O3, coated tool showed superior wear-resistance over the TiN/ Al2 O3 coated tool. The TiN coated tool showed the least wear resistance with respect to the other coated tools. Surface roughness appeared to increase with flank wear while oscillating for all the tested tools except for TiN coated tool. The coated tools produced lower surface roughness compared to the uncoated tool. The TiC/ Al2 O3/ TiN coated tool produced the lowest surface roughness of all the tools tested.

M. Kaladhar et. al [18] This research focuses on the fact that Austenitic Stainless Steel have been used extensively of largest volume of all the five families of Stainless Steels. It's characteristic is due to high ductility, high durability and excellent corrosion resistance. They pointed out on Its disadvantages also, that is it is difficult to cut material due to its high work hardening tendency, high ductility and low thermal conductivity Built up age . Also they explore on future research areas.

M. Kaladhar et. al [19] In this research researchers optimizes the process parameters using TAGUCHI Method. Also found out the influential parameters during Turning , using Analysis of Variance (ANOVA). They investigated the effect of process parameters on Surface Roughness and Material Removal Rate (MRR). They used PVD coated cermet inserts (TiCN-TiN) of 0.4 and 0.8 mm Nose radii. The results revealed that the feed and nose radius is the most significant process parameters on work piece surface roughness. However, the depth of cut and feed are the significant factors on MRR.

M. Kaladhar et. al [20] In this research researchers investigated the influence of c Pressure Vapour Deposition (PVD) and Chemical Vapour Deposition (CVD) coated cemented carbide inserts on the surface quality of the work piece when turning on AISI 304austenitic stainless steel work pieces, on computer numerical controlled (CNC) lathe. Taguchi's Design of Experiments (DOE) was used to analyze the effect of process parameters on surface roughness to obtain their optimal setting. The analysis of variance (ANOVA) is employed to analyze the influence of process parameters during turning. The results have shown that the improvement in average surface finish is obtained when machining with PVD coated insert (1.13 μm).The nose radius is the most significant process parameter (62.88% contribution) when turning with PVD insert. The cutting speed is the most significant factor (37.84% contribution) when turning with CVD insert.

M. Kaladhar et. al [21] They used Taguchi Method to determine the optimum process parameters for turning of AISI 304 austenitic stainless steel on CNC lathe. A Chemical vapour deposition (CVD) coated cemented carbide cutting insert is used which is produced by Duratomic technology of 0.4 and

0.8 mm nose radii. Tests were conducted at four levels of Cutting Speed Feed and Depth of Cut. The influence of these parameter were investigated on Surface Roughness and Material Removal Rate(MRR).The analysis of variance was used to analyze the influence of cutting parameters during Machining. The results revealed that cutting speed significantly (46.05%) affected the machined surface roughness values followed by nose radius (23.7%). The influence of the depth of cut (61.31%) in affecting material removal rate (MRR) was significantly large. The cutting speed (20.40%) was the next significant factor

S Saeedy et. al [22] This Research aims to optimize turning parameters of AISI 304 stainless steel. Turning tests have been performed in three different feed rates (0.2, 0.3, 0.4 mm/rev) at the cutting speeds of 100, 125, 150, 175and 200 m/min with and without cutting fluid. A design of experiments (DOE) and an analysis of variance (ANOVA) have been made to determine the effects of each parameter on the tool wear and the surface roughness.

They found that cutting speed has the main influence on the flank wear and as it increases to 175 m/min,the flank wear decreases. The feed rate has the most important influence on the surface roughness and as it decreases, the surface roughness also decreases.

Summary of Literature Review:

Based on the available Literature on Machining of AISI 304 Austenitic Stainless steel following Observations can be made.

1. Conventional Cutting fluids are dangerous affected Socially, economically and Environmentally. Very serious health hazards are associated of using conventional cutting fluids and disposal of it is very serious problem. There is a need of environment friendly green machining that is dry Machining.
2. Tool coatings can Improve machining by acting as a barrier between cutting tool and turned Material
3. Coated Carbide Inserts by CVD and PVD techniques are doing the same functions to some extent of cutting fluid. They accept some of heat generated at the time of Machining and to some extent retain microstructure of the material intact.
4. Vast experience needed while selection of proper process parameters, even though having Industrial experience using Manufacturers catalogue, favourable results cannot be obtained on output Response.
5. High Productivity is very much associated with the proper selection of cutting parameters that is high values of Cutting Speed, Depth of cut and feed rate.
6. Cutting Speed is the Most Significant factor on Surface Roughness, followed by tool coating.
7. Cutting Speed is the most Significant factor on Material Removal Rate (MRR), followed by depth of cut.
8. From the literature review, various parameters are identified, affecting the performance of AISI 304 Machining.

a) Cutting Parameters (Cutting Speed, feed rate, depth of cut)
b) Materials Parameters (Material composition, Mechanical and Physical Properties, material grain structure etc.)
c) Tool parameters (Tool geometry, Nose radius etc.)
d) Cutting tool coating techniques (CVD and PVD technique)
e) Uncontrolled Parameters.

3. CONCLUSION

The aim of the Review is to highlight the Major Research Studies carried out on AISI 304 Austenitic Stainless Steel turning. And various Methodologies used for the Analysis of Influence of process Parameters on Output Response. Many of the Researchers have focused on Optimization of Process Parameters and their Influence on Responses That is Material Surface Quality, MRR , and Low Power Consumption. Most of the Researchers used Taguchi Method for Design of Experiment (DOE). Some of the Researchers used Response Surface Methodology, Grey Relational Analysis, Regression Analysis. ANOVA has been applied to find out the most Significant factor and their influence on the Output Response. Out of all the Research work some of the Authors focus on PVD and CVD technique and combination of coating material on Cutting Inserts, which affect the output Response. So PVD and CVD Coated tool insert and Process Parameters are taken into account while doing future work on turning of AISI 304 Austenitic Stainless Steel.

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