Performance Evaluation of PVD and CVD multi Coated tool on AISI 304 Austenitic Stainless Steel

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ABSTRACT

Nowadays manufacturing industries are concerned with dimensional accuracy and Surface finish. The quality of manufactured products must be controlled in all manufacturing stages to reduce the number of rejected items and then reducing the total production cost. In the present day world, coated tools are used instead of uncoated tools for machining process, as they improve certain machining characteristics. Surface roughness (Ra) is one of the specified customer requirements in a machining process. It is essential to consider economy in addition to quality in any machining operations. Material Removal Rate is one of the Important feature for Manufacturer, they very much concerned of higher Material removal rate (MRR), productivity and cost effectiveness are the desired requirements for them. The higher value of MRR reduces the machining time and finally productivity of the system increases. In order to obtain optimal cutting parameters, manufacturing industries have depended on the use of handbook based information which leads to decrease in productivity due to sub-optimal use of machining capability this causes high manufacturing cost and low product quality. Hence, the proper selection of cutting tools and process parameters is essential to achieve the desired Material Removal Rate. Up till most of the Research work has been carried out by uncoated and coated carbide tools. No work of experimentation is Reported with PVD [TiAlN + Cr_2O_3] Coated tool by Researchers, also less work reported on Influence of tool geometry (Nose Radius) on Material Removal Rate. So the aim of this Experimental Investigation is to evaluate the Performance of PVD and CVD Multi layered Coated tool on AISI304 Austenitic stainless Steel, also investigate the effect of process parameters on Material Removal Rate (MRR) on CNC Lathe under Dry turning. In the Present work a Bar of Ø 28 x 80 mm long of AISI 304 Austenitic Steel is machined on CNC lathe, three process parameters (Cutting Speed m/min, feed rate mm/rev, and Depth of Cut) have been identified their influence on Output Response of Material Removal rate was investigated by using Taguchi's L9 Orthogonal Array. ANOVA is also applied to investigate the Optimum process parameters on Material Removal Rate.

KEYWORD: - *AISI 304 Machining, Material Removal Rate, Taguchi, ANOVA, CVD and PVD Coated tool.*

1. INTRODUCTION

Nowadays manufacturing industries are concerned with dimensional accuracy Surface finish and Material Removal Rate. The higher value of MRR reduces the machining time and finally productivity of the system increases. The quality of manufactured products must be controlled in all manufacturing stages to reduce the number of rejected items and then reducing the total production cost. Therefore, the proper selection, prediction and optimization of cutting tool and process parameters in machining processes have be important target the research workers in the machining field.[6]In the present day world, improving the productivity and the quality of the machined parts are the main challenges faced by the manufacturing industry. Modern cutting tools allow cutting at high speeds, thus increasing the volume of chips removed per unit time. Such objective requires better management of the machining system corresponding to cutting tool and machine tool-work piece combination in order to move toward a more rapid metal Removal rate. Alternatively the performance of cutting tools in machining operations is improved by using coatings. [9] The austenitic stainless steel consumed in large volumes (72%) among the other grades of stainless steels. It was reported that austenitic stainless steels come under the category of difficult to machine materials because of their low thermal conductivity and high mechanical and micro structural sensitivity to strain and stress rate [19] The AISI 304 austenitic stainless steel is the most widely used grade among all the grades of austenitic stainless steel. It is used for aerospace components and chemical processing equipment, for food, dairy, and beverage industries, for heat exchangers, and in Chemical Industry. [20] The aim of this Experimental Investigation is to evaluate the Performance of PVD and CVD Multi layered Coated tool on AISI304 Austenitic stainless Steel, also investigate the effect of process parameters on Material Removal Rate (MRR) on turning of AISI 304 Austenitic Stainless Steel on CNC Lathe under Dry turning. 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 revealed 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, and 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 were 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/Al_2O_3/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. 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. 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. 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. 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. Mohd Fazuri Abdullah et al [23] investigated the effect of different nose radius, cutting speeds and feed rates on the surface roughness of the AISI 306 stainless steel (SS316L), SS316L had been machined with cutting tool at 0.4 mm 0.8 mm, and 1.2 mm of nose radius, at 100,130, 170 m/min of cutting speeds and at 0.1, 0.125, 0.16 mm/rev of feed rates. Depth of cut was kept constant at 0.4 mm. It is seen that the insert nose radius, feed rates, and cutting speed have different effects on the surface roughness of SS316L. The lowest surface roughness was 0.225 μm in average, has been obtained when using insert with 1.2 mm of nose radius at the lowest feed rate (0.1 mm/rev). The highest surface roughness was 1.838 μm has been measured when using insert with 0.4 mm of nose radius at the highest feed rate (0.16 mm/rev). Results from analysis of variance (ANOVA) shown that the cutting speed was not contribute significantly effect on the surface roughness, compared to feed rate and insert nose radius. Surface roughness was decreased with decreasing of the feed rate. Machining with bigger insert nose radius has capability to obtain lower roughness than smaller insert nose radius. This phenomenon cause by maximizing uncut chip thickness which decreased with increasing of insert nose radius. Ibrahim Ciftci et el [24]In this research Author presents the results of experimental work in dry turning of austenitic stainless steels (AISI 304 and AISI 316) using CVD multi layer coated cemented carbide tools. The turning tests were conducted at four different cutting speeds (120, 150, 180 and 210 m/min) while feed rate and depth of cut were kept constant at 0.16 mm/rev and 1 mm, respectively. The cutting tools used were TiC/TiCN/TiN and TiCN/TiC/Al2O3 coated cemented carbides. The influences of cutting speed, cutting tool coating top layer and work piece material were investigated on the machined surface roughness and the cutting forces. The worn parts of the cutting tools were also examined under scanning electron microscope (SEM). The results showed that cutting speed significantly affected the machined surface roughness values. With increasing cutting speed, the surface roughness values decreased until a minimum value is reached. From the above literature it has been clear that lot of research have been reported by previous researchers on optimization of processes parameter on output response. But there is a lack of work Reported in selection of PVD and CVD Coated tool, having special emphasis on tool nose radius. So an Attempt has been made to investigate the influence of PVD and CVD Multi Layered coated tool with 0.4 mm Tool Nose radius, also the influence of process parameters on output response.

2. MATERIAL AND METHOD

2.1 Work piece Material

In this work, the turning was performed on cylindrical work pieces of dimensions Ø28 mm x 80 mm (length) of AISI 304 Austenitic Stainless Steel. The selection of this material as a work piece material, because it has excellent toughness, corrosion and oxidation resistance and ease of fabrication. Therefore it is used for a wide variety of applications such as in food industry, pipelines, valves and milk trucks cars Aerospace Industries and Chemical Industries etc. The chemical composition of AISI 304 Austenitic Stainless Steel is shown in table 1

Table 1. : Chemical composition of AISI 304 Austenic Stainless Steel Used in the Experimentation As per SAE 1970

Elements	C	Mn	Cr	Ni	Mo	S	P	Si	Fe
Composition (%wt.)	0.021	1.65	18.49	8.49	0.39	0.005	0.030	0.36	70.56

2.2 Tool Material and Machine Specifications

In this Experimentation work two cutting tool have been used for turning of AISI 304 Austenitic Stainless Steel. One Cutting tool have been coated by PVD method having [TiAlN+Cr2O3] Coating ,having latest chip breaking technology, specially designed for moderate to high speed applications. Other tool have been coated by CVD method having [TiCN+Al2O3+TiN] three coatings to make its very hard and high wear resistant applicable for high material removal and high speed application. Both the cutting Inserts have 0.4 mm tool nose radius have been chosen for Experimentation. Special consideration have been given on tool nose radius. Specifications of PVD and CVD Coated cutting Inserts are shown in table.2 Machine used for Turning operation is Lokesh TL 200. Having maximum turning diameter to maximum turning length of (260 mm x 300 mm) having positioning capacity of 0.006 mm. Having capacity of 15 KW, 415 volts and 3 Phase Supply.

2.3 Conduction of Experiment

All the Experiment has been carried out on Lokesh TL 200 CNC Machine. Machine used for turning operation is Lokesh TL 200. Having maximum turning diameter to maximum turning length of (260 mm x 300 mm) having positioning capacity of 0.006 mm. 15 KW Power 415 volts and 3 Phase Supply. Machine shown in figure1a. Taguchi's L9 Orthogonal Array has been used for three process Parameter and their three levels shown in table3.
Experimented Results of Output response of Material Removal Rate is tabulated in table 4. For PVD and CVD multi Layered Coated Tool Respectively.

Figure 1a. Lokesh TL-200 CNC Lathe Machine for Experimentation

Figure 1b. Machined Specimen AND Figure 1c. PVD [TiAlN + Cr_2O_3] and CVD [TiCN+Al2O3+TiN] Multi Layered Coated Insert (0.4 mm nose radius)

Table 2. Specifications of PVD and CVD Multi Layered Coated Cutting Tools

Coating Method and layers /Substrate	ISO GRADE	GEOMETRIC FORM	MANUFACTURER AND CODE
CVD(TiCN-Al2O3-TiN)/ Cemented carbide	4025	TNMG 2204	SANDVIK TN2204 (0.4 mm tool nose radius)
PVD (TiAlN/Cr2O3) / Cenmented Carbide	1115	TNMG 331	SANDVIK TN-MF 1115(0.4 mm tool nose radius)

Table 3. Process Parameters with their Levels

Sr. No.	**Process parameters**	**Notations**	**Coding Factors**	**Units**	**LEVELS**			**Ranges**
					Level 1	**Level2**	**Level3**	
1	Cutting Speed	v	A	m/min	120	180	220	120-220

2	Feed	f	B	mm/rev	0.10	0.15	0.20	0.10-0.20
3	Depth of Cut	d	C	mm	0.5	0.9	1.4	0.5-0.9

Table 4. Experimental Results of Machining of AISI 304 Austenitic Stainless Steel by PVD and CVD Multi Layered coated tool by Design Matrix of L9 Orthogonal Array

Expt.No.	**Input Parameters**				**Response Values PVD Coated Tool**		**Response Values CVD Coated Tool**	
	Speed (m/min)	**Feed (mm/rev)**	**Depth of Cut (mm)**		**MRR (mm^3 /min)**	**MRR S/N Ratio Values (mm^3 /min)**	**MRR (mm^3 /min)**	**MRR S/N Ratio Values (mm^3 /min)**
1	**120**	**0.10**	**0.5**		**2345.215**	**67.4037**	**2272.727**	**67.1309**
2	**120**	**0.15**	**0.9**		**4206.730**	**72.4774**	**5464.480**	**74.7510**
3	**120**	**0.20**	**1.4**		**8702.53**	**78.7929**	**10000.00**	**80.0000**
4	**180**	**0.10**	**0.9**		**3430.531**	**70.7072**	**3752.345**	**71.4861**
5	**180**	**0.15**	**1.4**		**6875.00**	**76.7455**	**8196.721**	**78.2728**
6	**180**	**0.20**	**0.5**		**3533.568**	**70.9643**	**4416.961**	**72.9025**
7	**220**	**0.10**	**1.4**		**5000.00**	**73.9794**	**5628.517**	**75.0079**
8	**220**	**0.15**	**0.5**		**2732.240**	**68.7304**	**3125.00**	**69.8970**
9	**220**	**0.20**	**0.9**		**5833.333**	**75.3183**	**7067.137**	**76.9849**

The Metal Removal Rate is Volume of Material Removed by Machine tool per unit time. The Material Removal Rate Can be calculated by following formula

$$MRR = \frac{W_i - W_f}{\rho_s t} mm^3 / \min$$

Where, *Wi* is the initial weight of work piece in *grams; Wf* is the final weight of work piece in *grams; t* is the machining time in minutes; ρ*s* is the density of AISI 304 austenitic stainless steel (8.0 x 10^{-3} g/mm3). Further ANOVA Analysis is carried out by using Minitab 21 software in order to determine most influencing parameters on the Metal Removal Rate. The "Larger the Better" Characteristics is selected to calculate the values of S/N ratio for Metal Removal Rate as shown in equation (1).

For Higher the Better

$(S/N)_{HB} = -10 \times \log (\sum (1/Y^{2)})$ where, Y = Response Value (1)

3. RESULTS AND DISCUSSION

In this Research work AISI 304 Austenitic Stainless steel cylindrical bar of Ø28x 80 mm were chosen for turning on Lokesh TL 200 series CNC machine. Prior to actual Experimentation the surface of the bar have cleaned and turned to 0.2 mm so that the excess material is removed. Actual Experimentation was performed using PVD and CVD coated tool under dry cutting Environment. Taguchi's L9 Orthogonal Array has been chosen for experimentation. Cutting Speed, feed rate and depth of cut have been chosen as in put process variables and for three variables and their three levels for each factor L9 Orthogonal array and Experimented results for Material Removal Rate have shown in table 4. According to design of experiment a statistical analysis was done for the experimental data obtained which are shown in table 4. from L9 experiments. By using minitab-21 software, the average performance and S/N ratio were calculated for various responses. Analysis of variance (ANOVA) was performed to identify the most or each significant control parameter and to quantify their effect on Output response.

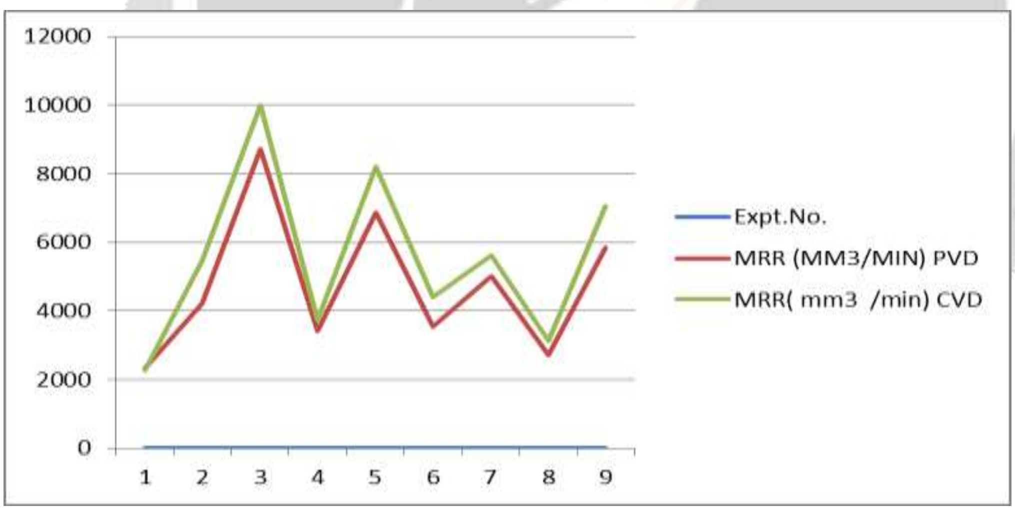

Figure 2. Material Removal Rate by PVD and CVD multi Layered coated tool

Figure 2. Shows the Comparative graphical representation of Metal Removal Rate of PVD and CVD Multi Layered Coated tool. At trial no. 3 (120mm/min, 0.2 mm/rev, and 1.4 mm) MRR values for PVD and CVD Both have highest values of 8702.53 mm^3/min and 10000.00 mm^3/ min respectively for same values of cutting speed, feed rate and depth of cut and the CVD Multi layered coated tool shows Improvement of **1297.47mm3/min in** MRR. . At trial no 7 (220, 0.1, 1.4) both have moderate values of MRR of **5000.00 mm^3/min and 5628.517 mm^3/min respectively.** Whereas at trial 1 (120, 0.10, 0.5) both PVD and CVD Coated tools have lowest values of MRR of **2345.215 mm^3/min** and **2272.727** mm^3**/min respectively.** From the values shown from the graph we can say that, for the same low values of cutting speed 120 m/min, high value of feed rate 0.2 mm/rev, and high value of depth of cut 1.4 mm, (120,0.2,and 1.4) CVD Multi Layered Coated tool shows 13% improvement in MRR. So for high metal removal rate CVD Multi Layered Coated Carbide Cutting tool will be the best option.

3.1 Effect of process parameters on Material Removal Rate for PVD Multi Layered Coated Tool.

From figure 3. and figure 4, It has been clear that, as Material Removal Rate is higher the better characteristics So the Optimal Parametric Combination for maximum MRR is **A1B3C3** for PVD Multi Layered Coated tool. Table 5. shows that Depth of Cut is the most significant factor on Material Removal Rate followed by feed rate and Cutting Speed respectively. From ANOVA table 6. It is clear that Depth of Cut is the most of significant factor on Material Removal Rate having 72.58% Contribution followed by feed rate 22.41% and finally Cutting Speed of 5.01%

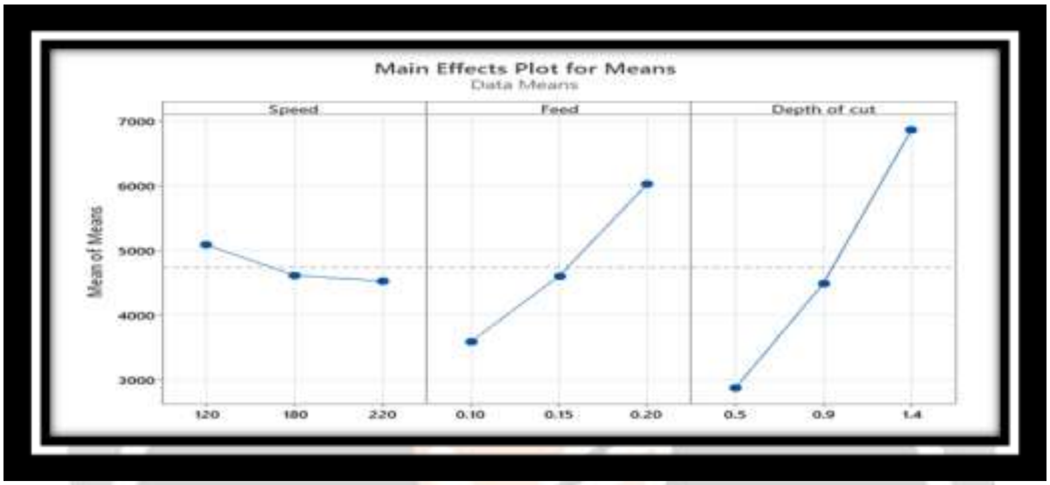

Figure 3. Main Effects Plot for Means [MRR] for PVD Multi Layered Coated Tool

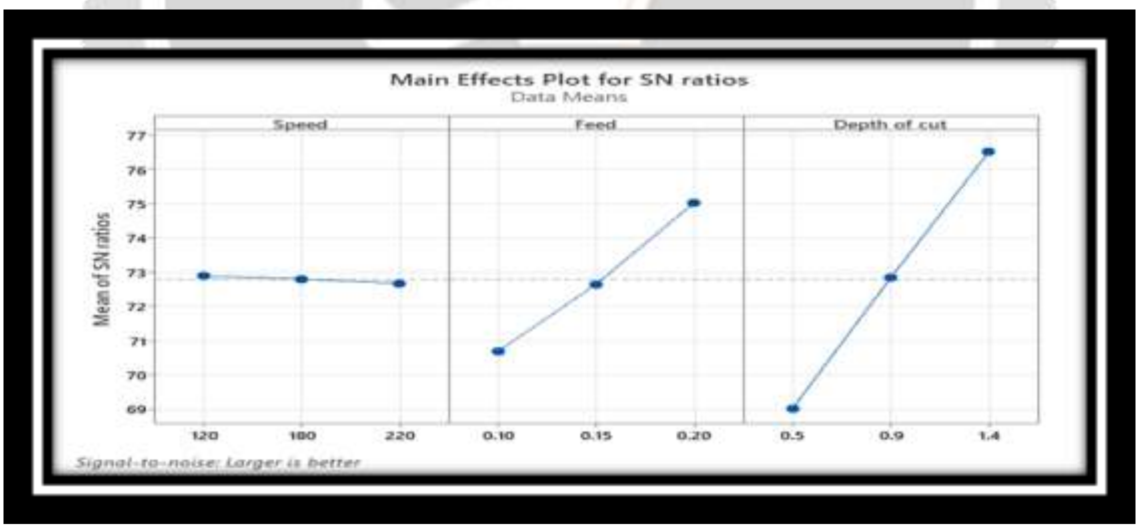

Figure 4. Main Effects Plot for SN ratios [MRR] for PVD Multi Layered Coated tool

Table 5. Response Table for S/N Ratios OF PVD Multi Layered Coated Cutting Tool

Level	Speed	Feed	Depth of Cut
1	72.89	70.70	69.03

2	72.81	72.65	72.83
3	72.68	75.03	76.51
Delta	0.22	4.33	7.47
Rank	3	2	1

Table 6. ANOVA for Material Removal Rate (S/N Data) For PVD Multi Layered Coated tool

Source	DOF	Adj. SS	Adj. MS	F	P	%Contribution
Speed	2	0.000007	0.000004	12.55	0.645	5.01
Feed	2	0.000021	0.000011	100.43	0.010	22.41
Depth of cut	2	0.000065	0.000032	309.52	0.003	72.58
Error	2	0.000000	0.000000			
Total	8	0.000086	0.000000			100
R Squared= (99.99)				**R-Squared (Adj) = (98.99)**		

3.2. *Effect of process parameters on Material Removal Rate for CVD Multi Layered Coated Tool.*

From figure 5 and figure 6 it has been clear that, as Material Removal Rate is higher the better characteristic type So the Optimal Parametric Combination for MRR is **A1B3C3** for CVD Multi Layered Coated tool. Table 7. shows that Depth of Cut is the most significant factor on Metal Removal Rate followed by feed rate and Cutting Speed respectively. From ANOVA table 8, it is clear that Depth of Cut is the most of significant factor on Material Removal Rate Having 65.10% Contribution followed by feed rate of 30.01% and finally Cutting Speed of 4.67% Contribution.

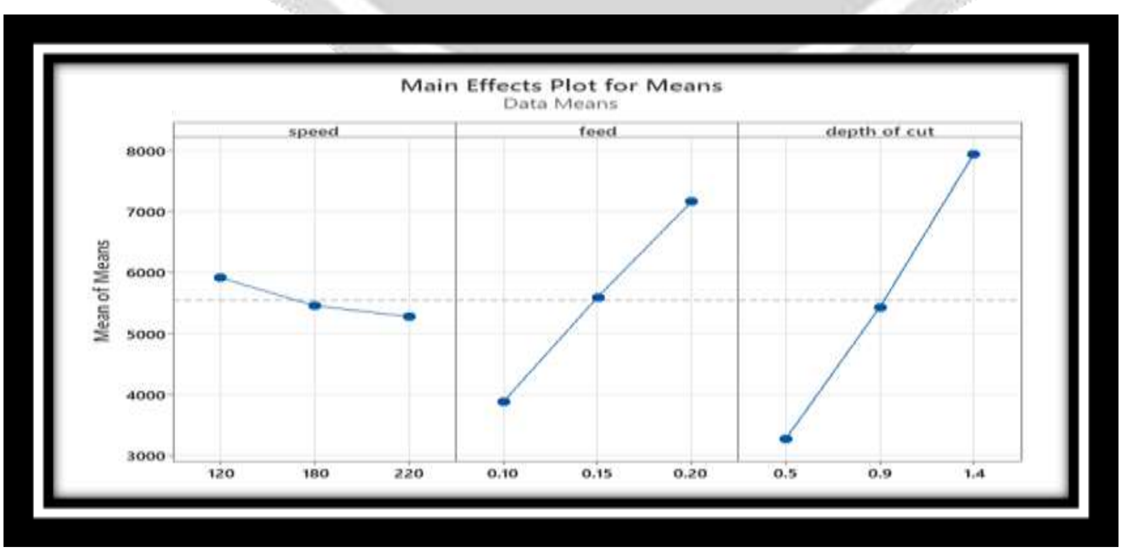

Figure 5. *Main Effect Plots for Means [MRR] For Machining of AISI 304 Austenitic Stainless Steel by CVD Multi Layered Coated tool*

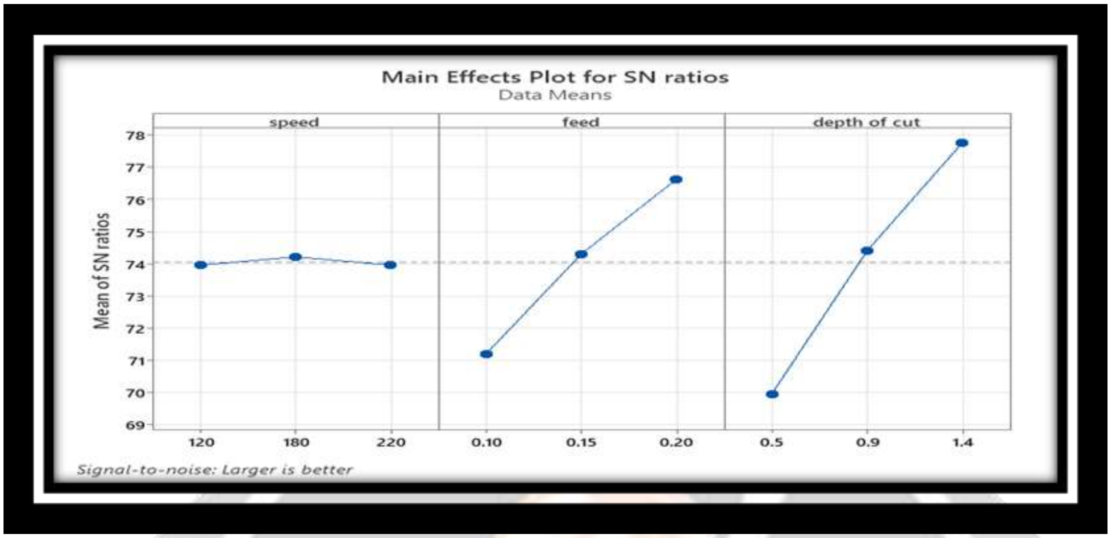

Figure 6. *Main Effect plot for S/N Ratio [MRR] For Machining of AISI 304 Austenitic Stainless Steel by CVD Multi Layered Coated tool*

Table 7. Response Table for S/N Ratios [MRR] for CVD Multi Layered Coaded Carbide tool

Level	Speed	Feed	Depth of Cut
1	73.96	71.21	69.98
2	74.22	74.31	74.41
3	73.96	76.63	77.76
Delta	0.26	5.42	7.78
Rank	3	2	1

Table 8. ANOVA for Material Removal Rate (S/N) For CVD Multi Layered Coated Cutting Tool

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Contribution
speed	2	0.00177	0.000886	18.44	0.693	4.67
feed	2	0.58824	0.294119	146.87	0.007	30.01
depth of cut	2	1.21219	0.606094	302.66	0.003	65.10
Error	2	0.00401	0.002003			0.222

Total	8	1.80620				100
R (Squared) = 99.80%				**R (Squared Adj) = 99.58%**		

4. CONCLUSIONS

On the basis of Experimental Results obtained during machining of AISI 304 Austenitic Stainless Steel following Conclusions are drawn as listed below.

1. For High Metal Removal Rate CVD Multi Layered Coated tool gave best Result compared to PVD Multi Layered Coated tool. For the same values of cutting Speed, feed rate and depth of cut CVD tool shows 13% Improvement in MRR.
2. Optimal Parametric Combination for maximum MRR is **A1B3C3** for PVD Multi Layered Coated tool. Depth of Cut is the most of significant factor on Material Removal Rate having 72.58% Contribution followed by feed rate of 22.41% and finally Cutting Speed of 5.01% contribution.
3. Optimal Parametric Combination for MRR is **A1B3C3** for CVD Multi Layered Coated tool. Depth of Cut is the most significant factor on Material Removal rate having 65.10% Contribution followed by feed rate 30..01% and finally Cutting Speed of 4.67%
4. From the Experimentation it is Investigate that Depth of Cut is the most significant factor on Material Removal Rate both by PVD and CVD Multi Coated tool.

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