OPTIMISATION OF PROCESS PARAMETERS OF PVD COATED CARBIDE TIP TOOLS (TiCN and TiAlN) BY TAGUCHI AND LEAN SIGMA TECHNIQUE

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*Abstract :*This paper describes some results of the research in optimization of PVD coated carbide tip tools insert (TiCN&TiAlN) by with and without heat treatment to reduce the wear resistance, lower surface roughness, increase material removal rate & reduce the cutting forces. The development of coatings for cutting tools is considered as a boon to the cutting tools evolution. Coatings have gone through several generations of development, due to the increasing demands of the industry, such as high-speed machining, dry machining, and machining of difficult-to-cut alloys, such as super alloys and titanium. The first coatings developed were hard coatings of TiN, TiC, TiCN or aluminum oxide, and were often used in a multiple layer; materials with these coatings outperformed uncoated high-speed steel inserts, due to their superior hardness and wear resistance. With new technologies in present manufacturing market the carbide cutting tools as became a necessary tool to produce different components in automotive.

Keywords: Carbide Tools, PVC Coated, Taguchi, Lean six sigma

1. INTRODUCTION

In this industrial era, machining of different materials is done daily the tools which are used must be long lasting in order to reduce the cost of expenditure on tools. In order to increase the tool life, the tool hardness must be greater than the material which is to be machined, and the machining process must be taken in a controlled temperature as the machining produces lot of heat when the depth of cut is increased suddenly, in that case a coolant must be used to reduce the temperature because due to heat material properties will vary. High productivity is the most important requirement in the machining process. But high productivity at the cost of poor surface finish is not acceptable. Surface roughness is considered as an index of product quality which makes it as the most desired outcome along with productivity. It measures the finer irregularities of the surface texture. A good quality turning surface can lead to improvement in strength properties and functional attributes of parts like friction, wearing, light reflection, heat transmission, coating and ability of distributing and holding a lubricant. Various process parameters viz. cutting speed, feed rate, depth of cut, cutting environment, cutting insert, tool geometry, work-piece material etc. are responsible for the ability to obtain the desired surface roughness. This study emphasizes on the use of coated inserts so as to reduce the use of lubricant and reduce environment pollution.

Now-a-days 80% of all machining operations are performed with coated carbide cutting tools. Hard turning had replaced application range of grinding in the areas of manufacturing shafts, gears, axles and other mechanical components made of materials having hardness range more than 45 HRC. This is due to the fact that hard turning reduces the cost per product in obtaining the surface finish close to grinding operation with higher productivity, less set up time, less costly equipment and an add on ability to machine complex contours. The specific cutting energy for the hard turning is found to be smaller than the specific grinding energy.

Trends toward machining difficult to cut materials lead to the development of high-performance thin layer coatings. Mostly carbide tools are processed by physical vapour deposition (PVD) so as to from a coating of material with properties like higher wear resistance and thermal shocks. Titanium based hard thin films are mostly used due to higher wear resistance, thermal shocks and corrosion property and also impart lubricity at the chip tool interface to reduce friction. Luca Settineri studied the properties and performances of innovative coated tools for turning EN24. Coatings surface qualification included SEM analysis.

THEORITICAL FRAMEWORK

The theoretical framework consists of collection of information about how to make the experimental work, cutting tool selection, right workpiece selection, which are input parameters & output parameters to be taken to overcome the objectives of the research.

1. Data & Sources of data

Collection of data about the research by different journal paper & reference paper to get different possible outcomes to achieve objectives.

1.1. Six Sigma

Six Sigma is a quality-control methodology developed in 1986 by Motorola, Inc. The method uses a data-driven review to limit mistakes or defects in a corporate or business process. Six Sigma emphasizes cycle-time improvement while at the same time reducing manufacturing defects to a level of no more than 3.4 occurrences per million units or events. True believers and practitioners in the Six Sigma method follow an approach called DMAIC, which stands for define, measure, analyse, improve, and control. It is a statistically driven methodology that companies implement as a mental framework for business process improvement. The ideology behind DMAIC is that a business may solve any seemingly unsolvable problem by following the DMAIC steps.

1.2. Lean

The term Lean manufacturing refers to the application of Lean practices, principles, and tools to the development and manufacture of physical products. Many manufacturers are using Lean manufacturing principles to eliminate waste, optimize processes, cut costs, boost innovation, and reduce time to market in a fast-paced, volatile, ever-changing global marketplace.

1.3. Lean Six Sigma

Lean Six Sigma is a fact-based, data-driven philosophy of improvement that values defect prevention over defect detection. It drives customer satisfaction and bottom-line results by reducing variation, waste, and cycle time, while promoting the use of work standardization and flow, thereby creating a competitive advantage. It applies anywhere variation and waste exist, and every employee should be involved.
Six Sigma implementation strategies can vary significantly between organizations, depending on their distinct culture and strategic business goals. After deciding to implement Six Sigma, an organization has two basic options: Implement a Six Sigma program or initiative, create a Six Sigma infrastructure.

1.4. PVD Coated Cutting Tools

PVD stands for Physical Vapor Deposition. PVD Coating refers to a variety of thin film deposition techniques where a solid material is vaporized in a vacuum environment and deposited on substrates as a pure material or alloy composition coating.

As the process transfers the coating material as a single atom or on the molecular level, it can provide extremely pure and high-performance coatings which for many applications can be preferable to other methods used. At the heart of every microchip, and semiconductor device, durable protective film, optical lens, solar panel and many medical devices, PVD Coatings provide crucial performance attributes for the final product. Whether the coating needs to be extremely thin, pure, durable or clean, PVD provides the solution.

1.5. Taguchi Method

This method, developed by Japanese engineer and statistician Genichi Taguchi, considers design to be more important than the manufacturing process in quality control and aims to eliminate variances in production before they can occur. The Taguchi method gauges quality as a calculation of loss to society associated with a product. In particular, loss in a product is defined by variations and deviations in its function as well as detrimental side effects that result from the product. Loss from variation in function is a comparison of how much each unit of the product differs in the way it operates. The greater that variance, the more significant the loss in function and quality. This could be represented as a monetary figure denoting how usage has been impacted by defects in the product. The Taguchi method of quality control is an approach to engineering that emphasizes the roles of research and development (R&D), and product design and development in reducing the occurrence of defects and failures in manufactured goods.

1.6. Heat Treatment

Heat treatment is the process of heating and cooling metals, using specific predetermined methods to obtain desired properties. Over time, a lot of different methods have been developed. Even today, metallurgists are constantly working to improve the outcomes and cost-efficiency of these processes. For that they develop new schedules or cycles to produce a variety of grades. Each schedule refers to a different rate of heating, holding and cooling the metal. These methods, when followed meticulously, can produce metals of different standards with remarkably specific physical and chemical properties.
In simple terms, heat treatment is the process of heating the metal, holding it at that temperature, and then cooling it back. During the process, the metal part will undergo changes in its mechanical properties. This is because the high temperature alters the microstructure of the metal. And microstructure plays an important role in the mechanical properties of a material. The final outcome depends on many different factors.

1.7. MiniTab

Minitab is a software product that helps you to analyse the data. This is designed essentially for the Six Sigma professionals. It provides a simple, effective way to input the statistical data, manipulate that data, identify trends and patterns, and then extrapolate answers to the current issues. It provides a simple, effective way to input the statistical data, manipulate that data, identify trends and patterns, and then extrapolate answers to the current issues. This is most widely used software for the business of all sizes - small, medium and large. Minitab provides a quick, effective solution for the level of analysis required in most of the Six Sigma projects.

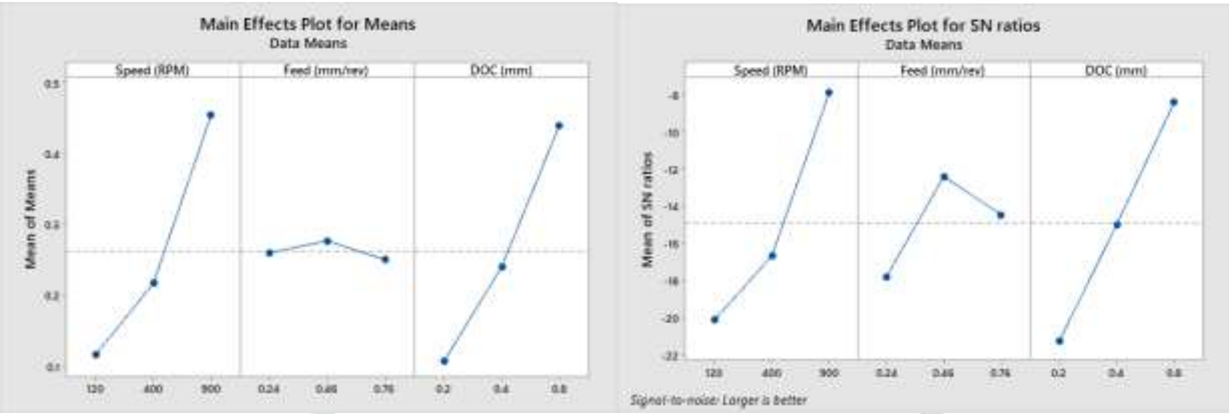
Tabel:1. Model Response tabel of SN & Means

Response Table for Signal to Noise Ratios

Level	Speed (RPM)	Feed (mm/rev)	DOC (mm)
1	-20.160	-17.835	-21.292
2	-16.691	-12.418	-15.012
3	-7.870	-14.467	-8.416
Delta	12.290	5.418	12.876
Rank	2	3	1

Response Table for Means

Level	Speed (RPM)	Feed (mm/rev)	DOC (mm)
1	0.1163	0.2600	0.1067
2	0.2167	0.2767	0.2400
3	0.4533	0.2497	0.4397
Delta	0.3370	0.0270	0.3330
Rank	1	3	2



Experimental Data Collection

1.1. **EN24T** steel is a popular grade of through-hardening alloy steel due to its excellent machinability in the "T" condition. EN24T is used in components such as gears, shafts, studs and bolts, its hardness is in the range 248/302 HB. EN24T can be further surface-hardened to create components with enhanced wear resistance by induction or nitriding processing. EN24 is a very high strength steel alloy which is supplied hardened and tempered. The grade is a nickel chromium molybdenum combination - this offers high tensile steel strength.

1.2. Titanium aluminium is a refractory compound that possesses a number of valuable properties, such as high micro hardness and chemical and thermal stability. **TiAlN** has a variety of applications: as a component in special refractories as a material for crucibles for anoxic casting of metals, and as a precursor for wear-resistant and has a colour of violet bronze. Colour Bright Grey, Serving Temperature – 900^{0}C.

1.3. **TiCN**is bright grey in colour. The coating thickness is 1-4 micro meter. It possesses a variety of properties such as high micro hardness and chemical and thermal stability. Colour – Bright Grey, Serving Temperature – 900^{0}C.

2. Literature Survey

1. The article ‘Effective decision support to implement lean and six sigma methodologies in the manufacturing and service sectorspublished on 17 Oct 2008, by M.K. Tiwari a , Jiju Antony b & D.C. Montgomery c a Department of Industrial Engineering and Management, Indian Institute of Technology, Kharagpur, 721302, India E-mail: b Department of Design, Manufacture and Engineering Management, University of Strathclyde, James Weir Building, 75 Montrose St, Glasgow, G1 1XJ, UK E-mail: c Department of Industrial and Management Systems Engineering , Arizona State University, Tempe. The papers included in this issue address prominent concepts and techniques in the context of lean and six sigma methodology, the current trends in implementation of lean and six sigma methodologies, difficulties confronted by the researchers as well as the industry practitioners to arrive at appropriate decision demands a knowledge base and research material at one place.

2. Effect of work material hardness and cutting parameters on performance of coated carbide tool when turning hardened steel: An optimization approach Satish Chinchanikar, S. K Choudhury, Measurement 46 (4), 1572-1584, 2013. In present work performance of coated carbide tool was investigated considering the effect of work material hardness and cutting parameters during turning of hardened AISI 4340 steel at different levels of hardness. The correlations between the cutting parameters and performance measures like cutting forces, surface roughness and tool life, were established by multiple line a regression model. The correlation coefficients found close to 0.9, showed that the developed models are reliable and could be used effectively for predicting the responses within the domain of the cutting parameters. Highly significant parameters were determined by performing an Analysis of Variance (ANOVA). Experimental observations show that higher cutting forces are required for machining harder work material. These cutting forces get affected mostly by depth of cut followed by feed. Cutting speed, feed and depth of cut having an interaction effect on surface roughness. Cutting speed followed by depth of cut become the most influencing factors on tool life; especially in case of harder workpiece. Optimum cutting conditions are determined using response surface methodology (RSM) and the desirability function approach. It was found that, the use of lower feed value, lower depth of cut and by limiting the cutting speed to 235 and 144m/min; while turning 35 and 45 HRC work material, respectively, ensures minimum cutting forces, surface roughness and better tool life.

3. Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning December 2007 Materials and Design 28(4):1379-1385 MuammerNalbant, Gazi UniversityH. Gökkaya, Gökhan Sur, Karabuk University. In this study, the Taguchi method is used to find the optimal cutting parameters for surface roughness in turning. The orthogonal array, the signal-to-noise ratio, and analysis of variance are employed to study the performance characteristics in turning operations of AISI 1030 steel bars using TiN coated tools. Three cutting parameters namely, insert radius, feed rate, and depth of cut, are optimized with considerations of surface roughness. Experimental results are provided to illustrate the effectiveness of this approach.

4. The effects of cryogenic treatment on cutting toolsSatish Kumar, Nitin K Khedkar,BhushanJagtap, TP Singh IOP Conference Series: Materials Science and, Engineering 225 (1), 012104, 2017. Enhancing the cutting tool life is important and economic factor to reduce the tooling as well as manufacturing cost. The tool life is improved considerably by 92 % after cryogenic treatment. The cryogenic treatment is a one-time permanent, sub-zero heat treatment that entirely changes cross-section of cutting tool. The cryogenic treatment is carried out with deep freezing of cutting tool materials to enhance physical and mechanical properties. The cryogenic treatment improves mechanical such as hardness, toughness and tribological properties such as wear resistance, coefficient of friction, surface finish, dimensional stability and stress relief. The deep cryogenic treatment is the most beneficial treatment applied on cutting tools. The cryogenic treatment is the most advanced heat treatment and popular to improve performance of the cutting tool. The optimization of cryogenic treatment variables is necessary to improve tool life. This study reviews the effects of cryogenic treatment on microstructure, tribological properties of tool steels and machining applications of cutting tool by investigating the surface and performing the surface characterization test like SEM. The economy of cutting tool can be achieved by deep cryogenic treatment.

3. PROBLEM STATEMENT

A good quality turning surface can lead to improvement in strength properties and functional attributes of parts like friction, wearing, light reflection, heat transmission, coating and ability of distributing and holding a lubricant. Various process parameters viz. cutting speed, feed rate, depth of cut, cutting environment, cutting insert, tool geometry, work-piece material etc. are responsible for the ability to obtain the desired surface roughness. This study emphasizes on the use of coated inserts so as to reduce the use of lubricant and reduce environment pollution.

The main aim of the project is to increase the material removal rate and to decrease the cutting forces by Taguchi L9 array technique. Here we have performed the cutting operations by PVD coatings on carbide tools to get TiAlN and TiCN carbide tip tools. The experiments were conducted for the tools by varying cutting parameters such as Speed, Feed, Depth of Cut and the output values such as material removal rate and cutting forces are measure using weighing machine and stop watch and lathe tool dynamometer.

The material removal rate and cutting forces are noted down before and after heat treatment of the above-mentioned cutting tools. These results are analyzed by using Minitab 19 software. The Taguchi analysis is applied to get optimal parametric vales for material removal rate and cutting forces versus cutting parameters (Speed, Feed, Depth of Cut). The results of the analysis such as response table for signal to noise ratios and also response table for means are obtained similarly optimal plots for material removal rate and cutting forces also obtained. by comparing the delta values, we are going to rank the cutting parameters which signifies the most significant value on MRR and cutting forces. The optimal plots are used to find best process parameters on material rerate and cutting forces before heat treatment and after heat treatment in order to understand the influence or improvement of MRR and cutting forces on coated TiCN and TiAlN coated tools.

4. OBJECTIVES

- To increase the wear resistance and to get higher surface finish by giving different depth of cut, feed rate, MRR and cutting forces parameters and suggesting which is better by analyzing the results of experimental work.
- By optimizing the cutting Parameters (Speed, Feed, Depth of Cut) using Taguchi method, it alters the material removal rate and cutting forces.
- The manufacturing lead time decreases (when removal rate is more, the lead time decreases).
- By using lean six sigma approach to improve the issues on carbide coated cutting tools and taguchi method to find the parameters issues.

5. METHODOLOGY

By collecting the uncoated tools from the tool tip shop then collecting the information about coating material coating them with TiAlN&TiCN coating material with the help of **OerlikonBalzers Coating India Pvt. Ltd**. Collecting information about workpiece material selection the experimentation procedure about Taguchi L9 Table and conducting experiment with Lathe machine and tabulating values by varying different inputs like feed, depth of cut & speed. Note experimental reading for material removal rate (MRR) by weighing the material removed during each operation and values of cutting forces by using Lathe tool dynamometer connected to Lathe tool. After Conducting the experimentation for without heat treatment TiAlN&TiCN Coated tip inserts then TiAlN&TiCN inserts are treated with heat treatment then cryogenic cooling to get a

better result. Then experimental values are tabulated after experimenting heat treated inserts with the help of minitab by using Taguchi method the analysis is done. In the present study, an attempt has been made to investigate the effect of process parameters on performance characteristics in finish hard turning of EN24 steel using cemented carbide tool and there by optimization of turning of EN24 steel by taguchi method. The cutting speed, feed and depth of cut were used as the process parameters whereas the cutting force and material removal rate were selected as performance characteristics. The L9 orthogonal array based on design of experiments was used to conduct the experiment. The cutting speed was identified as the most influential process parameter on cutting force and feed was identified as the most influential process parameter on material removal rate and surface finishing.

Table 2 : Design of experiment for main factors (input)

Main Factor	Level 1	Level 2	Level 3
Cutting speed rpm	$V_1 = 120$	$V_2 = 400$	$V_3 = 900$
Feed rate mm/rev	$F_1 = 0.24$	$F_2 = 0.46$	$F_3 = 0.76$
Depth of cut mm	$d_1 = 0.2$	$d_2 = 0.4$	$d_3 = 0.8$

Table 2 shows the different experimental parameters which are used as inputs for machining EN-24 steel material. Each parameter is at 3 different levels. For the given 3 factors at 3 levels, the considered Taguchi's orthogonal array is L9. The table 3 gives L9 orthogonal array as shown in below.

Table 3 : Taguchi L9 Orthogonal array experiment parameters

Experiment Trails	Cutting speed	Feed rate	Depth of cut
L_1	V_1	f_1	d_1
L_2	V_1	f_2	d_2
L_3	V_1	f_3	d_3
L_4	V_2	f_1	d_2
L_5	V_2	f_2	d_3
L_6	V_2	f_3	d_1
L_7	V_3	f_1	d_3
L_8	V_3	f_2	d_1
L_9	V_3	f_3	d_2

The below **TABLE 3** shows the experimental readings of **TiCN** carbide tip tool insert **without heat treatment** to know behavior of TiCN insert on workpiece with the lathe & lathe tool dynamometer.
Machining process is carried out according to Taguchi L9 table by varying feed rate, depth of cut and spindle speed. The EN24 is a high strength steel alloy of hardness 248/302 HB. The EN24 work piece is machined with PVD coated TiCN and the results are tabulated below.

TABLE 4Cutting forces and MRR results forTiCN

Sl No	Speed In rpm	Feed mm/rev	DOC mm	Intial In grams	Final In grams	Diff In grams	MRR In g/s	Fy In kgf	Fz In kgf	Time In sec
1	120	0.24	0.2	878.4	874.2	4.2	0.046	37	20	90
2	120	0.46	0.4	874.2	868.6	5.6	0.13	70	30	40.6
3	120	0.76	0.8	868.3	862.6	5.7	0.16	98	44	35.13
4	400	0.24	0.4	862.6	860.2	2.4	0.07	-42	23	31.47
5	400	0.46	0.8	860.2	850.7	9.5	0.49	86	23	19.36
6	400	0.76	0.2	850.7	850.1	0.6	0.056	50	30	10.53
7	900	0.24	0.8	850.1	843	7.4	0.58	45	26	12.6
8	900	0.46	0.2	843	841.5	1.5	0.19	23	18	7.8
9	900	0.76	0.4	841.5	838.2	3.3	0.47	39	23	7

The **Table 4** are the tabulated values obtained by **TiAlN** carbide tip tool insert **without heat treatment** to know the reading of cutting forces &**MRR.**
This time the machining is carried out on the EN24 work piece using PVD coated TiAlN cutting tool and the results are tabulated below. The presence of aluminum in the coating decreases the friction between cutting tool and work piece.

TABLE 5 Cutting forces and MRR results forTiAlN

Sl no	Speed In rpm	Feed mm/rev	DOC in mm	Initial In grams	Final In grams	Difference In grams	MRR In g/s	Fy In kgf	Fz In kgf	Time In sec
1	120	0.24	0.2	941.8	939.6	2.2	0.03	34	12	72.7
2	120	0.46	0.4	939.6	934.2	5.4	0.086	72	34	62.56
3	120	0.76	0.8	934.2	929.3	4.9	0.167	107	44	29.32
4	400	0.24	0.4	929.3	923.0	7.3	0.25	21	20	28.59
5	400	0.46	0.8	923	916.8	6.2	0.41	79	37	15.05
6	400	0.76	0.2	916.8	915.3	1.5	0.14	41	26	10.58
7	900	0.24	0.8	915.3	893.1	7.4	0.58	29	27	15.84
8	900	0.46	0.2	893.1	890.6	2.5	0.22	44	15	11.27
9	900	0.76	0.4	890.6	890	0.6	0.13	44	26	4.6

The **Heat treated TiCN&TiAlN** carbide tip tool inserts then gone through different process of heat treatment then gradually cooled with the air. Then **TiCN&TiAlN** insert is used for experimental use to do different operation by using lathe & lathe tool dynamometer to get values. The results are then used for analysis by using Minitab.

The **TABLE 6**experimental values after tabulated based on operation carried out using Lathe by varying the operational parameters like DOC, feed, &speed of **TiCN**.

TABLE 6Cutting forces and MRR results forTiCN

Exp No	Speed rpm	Feed mm/rev	DOC mm	initial grams	Final grams	Diff grams	MRR In g/s	Fy Kgf	Fz Kgf	Time Sec
1	120	0.24	0.2	755.6	751.3	4.3	0.04	36	20	87
2	120	0.46	0.4	751.3	745.65	5.65	0.14	67	28	38
3	120	0.76	0.8	745.65	739.85	5.8	0.169	92	41	34.2
4	400	0.24	0.4	739.85	737.35	2.5	0.08	40	19	30.59
5	400	0.46	0.8	737.35	727.65	9.5	0.49	77	19	19.10
6	400	0.76	0.2	727.65	726.85	0.8	0.08	48	27	10
7	900	0.24	0.8	726.85	719.25	7.6	0.66	34	21	11.47
8	900	0.46	0.2	719.25	717.7	1.55	0.2	21	17	7.5
9	900	0.76	0.4	717.7	714.3	3.4	0.5	37	21	6.54

Below **TABLE 7**are the tabulated values by using **TiAlN**carbide tip insert by doing different operations on lathe machine. The **TiAlN**carbide tip insert is gone through heat treatment process & gradually cool.

TABLE 7 Cutting forces and MRR results forTiAlN

Exp N1o	Speed rpm	Feed mm/rev	DOC mm	Initial grams	Final grams	Diff grams	MRR In g/s	Fy Kgf	Fz Kgf	Time Sec
1	120	0.24	0.2	688.6	684.3	4.3	0.04	35	18	88
2	120	0.46	0.4	684.3	678.65	5.65	0.14	65	29	40
3	120	0.76	0.8	678.65	672.85	5.8	0.16	90	41	34.57
4	400	0.24	0.4	672.85	670.35	2.5	0.08	40	21	31
5	400	0.46	0.8	670.35	663.35	7	0.37	80	22	18.54
6	400	0.76	0.2	663.35	662.65	0.7	0.06	45	27	10.10
7	900	0.24	0.8	662.65	655.15	7.6	0.66	23	19	11.4
8	900	0.46	0.2	655.25	653.5	1.55	0.2	23	17	7.3
9	900	0.76	0.4	653.5	650.1	3.4	0.52	35	21	6.58

6. RESULTS AND DISCUSSION

The response table & figure of Means and Signal to Noise Ratios are obtained with the help of MiniTab 19 software analysis of Taguchi Method. Various inputs such as DOC (mm), speed (rpm) & feed (mm/rev) using L9 taguchi orthogonal array are used to get outputs in terms of MRR (mm) & Cutting forces (kgf). The experimental results are analyzed in Minitab 19 software and the Tauguchi analysis is applied. The analysis was done for TiCN&TiAlN carbide inserts with & without heat treatment

TABLE 8 Response Table for MRR TiCN without Heat Treatment

Table 8 (a) Response Table for Signal to Noise Ratios

Level	Speed (RPM)	Feed (mm/rev)	DOC (mm)
1	-20.128	-18.191	-22.069
2	-18.110	-12.781	-15.792
3	-8.571	-15.837	-8.948
Delta	11.556	5.411	13.120
Rank	2	3	1

Table 8 (b) Response Table for Means

Level	Speed (RPM)	Feed (mm/rev)	DOC (mm)
1	0.11200	0.23200	0.09733
2	0.20533	0.27000	0.22333
3	0.41333	0.22867	0.41000
Delta	0.30133	0.04133	0.31267
Rank	2	3	1

The **Table 8** Response table of **SN ratios & Means** shows analysis of the experimental results which were obtained after conducting experiments with TiCN cutting tool to machine EN24 material on lathe machines. The both response **Table 8 (a)** &**Table 8 (b)** shows the depth of cut (**DOC)** is the most influential factor to get high Material removal rate

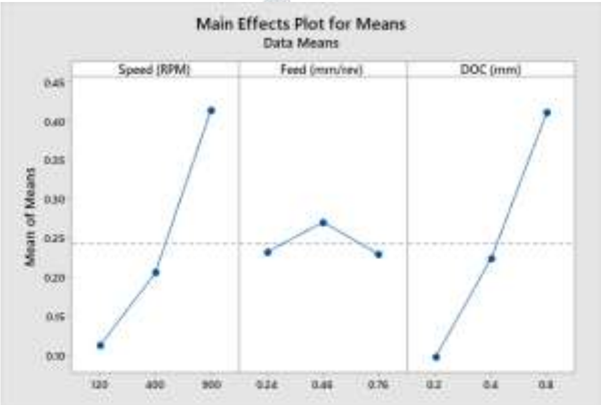


Fig 1 MRR TiCN without Heat Treatment

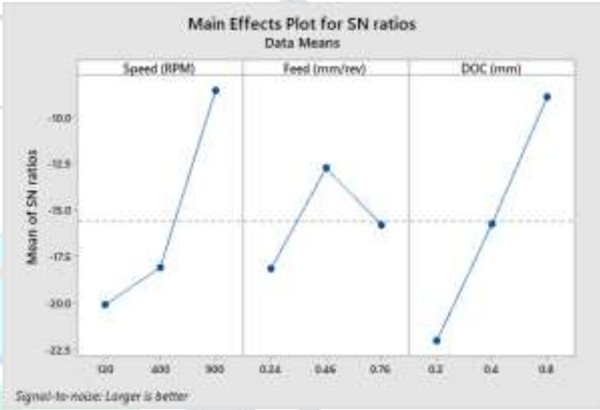


Fig2 MRR TiCN without Heat Treatment

The **Fig 1**&**2** are the graphical plots obtained from minitab software that shows the response for material removal rate when machined with TiCN carbide insert on EN24 material. From the figure we can conclude that the material removal rate (MRR) is maximum at a speed 900rpm, 0.46 mm of feed/rev& 0.8 mm.

TABLE 9 Response Table for Cutting Force TiCN without Heat Treatment

Table 9 (a) Response Table for Signal to Noise Ratios

Level	Speed (RPM)	Feed (mm/rev)	DOC (mm)
1	5.945	6.179	10.598
2	6.152	7.322	7.126
3	9.129	7.725	3.501
Delta	3.184	1.546	7.097
Rank	2	3	1

Table 9 (b) Response Table for Means

Level	Speed (RPM)	Feed (mm/rev)	DOC (mm)
1	49.83	37.00	29.67
2	42.33	41.67	37.83
3	33.83	47.33	58.50
Delta	16.00	10.33	28.83
Rank	2	3	1

Table 9response table of **SN &Means**: Response table of **SN ratios & Means** shows analysis of the experimental results which were obtained after conducting experiments with TiCN cutting tools without heat treatment to machine EN24 material on lathe machines. The both response **Table 9 (a)** &**Table 9 (b)** shows the depth of cut **DOC** is the most influential factor to get nominal cutting forces.

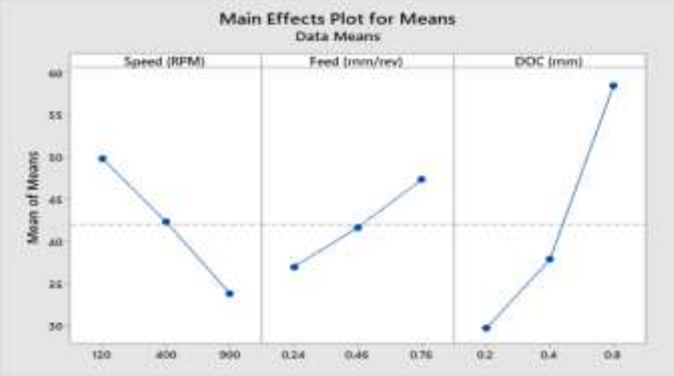


Fig3 Cutting Force TiCN without Heat Treatment

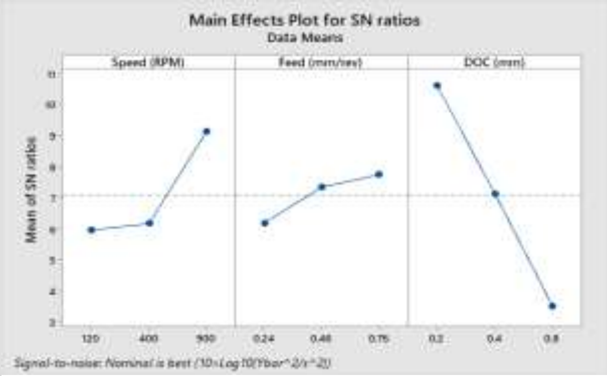


Fig 4 Cutting Force TiCN without Heat Treatment

The **Fig 3**&**4** are the graphical plots obtained from Minitab software that shows the response for cutting forces when machined with TiCN carbide insert on EN24 material. From the figure we can conclude that the MRR is maximum at a speed of 900rpm, 0.76 mm of feed/rev& 0.2 mm of DOC.

When the machining of EN24 is done with **TiCN**. The material removal rate is increased from 0.57 gm/s to 0.66 gm/s.The cutting forces is decreased from Fy = 45 Kgf, to Fy = 34 Kgf, and from Fz = 26 Kgf to Fz = 21 Kgf .From the above, we can conclude that, after heat treatment, the material removal rate is increased by 9% and the cutting forces is decreased (By Fy =11%, Fz = 5%).Material removal rate (MRR) is optimal at a speed 900rpm, 0.46 mm of feed/rev& 0.8 mm. without heat treatment and Material removal rate (MRR) is optimal at a speed of at 900rpm, 0.46 mm of feed/rev& 0.8 mm of DOC.From the above results we can conclude that the optimal parameter settings are same for MRR before and after heat treatment.

From the above results we can conclude that the optimal settings changes for cutting forces before and after heat treatment. The depth of cut is the most influential factor on material removal rate before and after heat treatment.The depth of cut is most influential factor on the cutting forces before heat treatment and speed is the most influential factor on the cutting forces after heat treatment. Similarly, when the machining of EN24 is done with **TiAlN**. The material removal rate is increased from0.58 gm/s to 0.66 gm/s.

The cutting force is decreased from Fy = 29 Kgf, to Fy = 23 Kgf, from Fz = 27 Kgf to Fz = 19 Kgf. From the above, we can conclude that, after heat treatment, the material removal rate is increased by 8% and the cutting force is decreased (By Fy = 6%, Fz = 8%). By comparing **TiAlN** and **TiCN** after heat treatment with without heat treatment the material removal rate (MRR) is increased and cutting forces is decreased.

7. CONCLUSION

Analysing the experiental result of**TiCN**&**TiAlN**coated carbide tip tool insert with and without heat treatment. From the above results we can conclude that the optimal settings changes for cutting forces are different before and after heat treatment.The depth of cut is the most influential factor on cutting forces before and after heat treatment. The speed is most influential factor on the cutting forces before heat treatment and the depth of cut is the most influential factor on the cutting forces after heat treatment. By comparing TiAlN and TiCN after heat treatment with without heat treatment the material removal rate (MRR) is increased and cutting forces is decreased.

REFERENCES

1. DiptiKanta Das, Ashok Kumar Sahoo, Ratnakar Das, B.C. Rotara, Investigations on hard turning using coated insert: Grey based Taguchi and regression methodology, Procedia Materials Science 6(2014) 1351-1358.

2. Impact of fracture toughness on surface properties of PVD coated cold work tool steel BojanPodgornik, M Sedlaček, M Čekada, Staffan Jacobson, B Zajec Surface and Coatings Technology 277, 144-150, 2015

3. Investigation of cutting parameters affecting on tool wear and surface roughness in dry turning of Ti-6Al-4V using CVD and PVD coated tools YH Çelik, E Kilickap, M Güney - Journal of the Brazilian Society of …, 2017 – Springer

4. R. Karthikeyan, KosarajuSatyanarayana, Pujari Anil Kumar, Application of Taguchi-Grey Method to optimize turning operations on EN24 with multiple performance characteristics, Materials Today Proceedings 5(2108) 17958-17967.

5. High temperature wear resistance of (TiAlN) PVD coating on untreated and gas nitride AISI H13 steel with different heat treatments R Rodriguez-Baracaldo, JA Benito, ES Puchi-Cabrera… - Wear, 2007 – Elsevier.

6. Cryogenic treatment to augment wear resistance of tool and die steels DM Lal, S Renganarayanan, A Kalanidhi - Cryogenics, 2001 – Elsevier

7. M.B Karamis, H. Sert, the role of PVD TiN coating in wear behavior of aluminium extrusion die, Wear 217(1998).

8. Nageshwaran Tamil Alagan, Pavel Zeman, Philipp Hoier, Tomas Beno, Utaklement, Investigation of micro-structured cutting tools used for face turning of alloy 718 with high-pressure cooling, Journal of Manufacturing process 37(2019) 606-616.

9. Horng, J-T., Liu, N.M., Chiang, K.T., 2008. Investigating the machinability evaluation of Hadfield steel in the hard turning with Al2O3/TiC mixed ceramic tool based on the response surface methodology, Journal of Materials Processing Technology 208 (1-3), 532-541.

10. Lalwani, D.I., Mehta, N.K., Jain, P.K., 2008.Experimental investigations of cutting parameters influence on cutting forces and surface roughness in finish hard turning of MDN250 steel, Journal of Materials Processing Technology 206 (1-3), 167-179.

11. Comparison of TiN-coated tools using CVD and PVD processes during continuous cutting of Ni-based superalloys S Koseki, K Inoue, S Morito, T Ohba, H Usuki - Surface and Coatings …, 2015 – Elsevier.