MANTECH Publications

Journal of Advance Manufacturing System and Technology
Volume 4, Issue 1, January- June, 2019

Experimental Analysis of Three Different Types of Low Friction Coating with HSS T-42 as Base Material

Amol Suresh Nankar*, D. A. Deshmukh**

Lecturer, Professor***

Department of Mechanical Engineering

SYCET Aurangabad

Corresponding author's email id: *amolnankar@gmail.com*, dipachdesh@gmail.com***

Abstract

Cutting operation is very essential aspect in manufacturing scenario. Application of coating on tool surface helps to improve tribological properties of surface such as wear and coefficient of friction of the surface. Cutting life time of a tool material is significantly affected by wear. The performance of various coatings on tool material is inspected by studying the variation of its two properties viz. wear & coefficient of friction. These essential tribological properties have been evaluated by using pin on disc test. This paper is focused on various low friction coatings such as TiN, CrN and DLC coating on High speed steel T-42 pin as a base material. This paper deals with the study of performance parameters like speed, sliding distance and load compared between different coated HSS-T42 pin base materials. Taguchi method is used under the performance parameter & L9 orthogonal array is selected to perform experiment on pin on disc of the specimen. The EN31 steel material is selected as work piece material. The response value found out by using coefficient of friction which was obtained from pin on disc test. Scanning Electron Microscopy (SEM) analysis for compared different coated pin for micro structural test.

Keywords: *HSS T-42 pin, Wear, Coefficient of Friction, TiN, CrN, DLC.*

INTRODUCTION

The manufacture of any product component involves cutting tool as a fundamental and vital constituent. The tool life is always taken into consideration during the analysis of tribological properties such as wear and coefficient of friction. So for, the analysis regarding testing of wear & coefficient of friction has been performed checked with different coatings on HSS (High Speed Steel) T-42 pin. The HSS T-42 grade is widely used as tool material since it is easily available at comparatively lower cost than other graded tool materials. To ensure a product of substantial and satisfactory quality, a cutting tool is obliged to have three fundamental properties viz. Hardness, Toughness, Wear resistance.

Firstly, cutting tool material should be harder than the work piece material upon which operation is to be performed. Furthermore, tool must be capable to withstand high temperature encountered during metal cutting process. Single point cutting tool performs operations on lathe machine, shaper machine, planer machine, slotting machine through removal of material by means of one cutting edge. Milling & drilling tool are multipoint tools used for gear cutting, drilling, boring, reaming and slotting operations. The coatings are used on tool material due to properties of high hardness, wear resistance, toughness, good chemical stability, refractoriness, anti-oxidation capability, which are highly helpful in high speed machining and metal forming industries. In high speed machining operations, the major problem which is encountered is the high rate of tool wear, thereby causing the reduction in cutting tool life. This is due to highest temperature on tool tip and work piece material. With the growing industry of coating tools & new development of coating process, there is need to compare various low friction coating and select the best coating by performing experiment.

To produce quality product, a cutting tool must have three characteristics:

1. ***Hardness:*** hardness and strength at high temperatures.
2. ***Toughness:*** so that tools do not chip or fracture.
3. ***Wear resistance:*** having acceptable tool life before needing to be replaced.

Companies and researchers in the field of cutting tools are in the continuous search of coatings capable of improving the behaviour of cutting tools for aerospace and biomedical applications (mainly

manufactured of carbides) in terms of wear resistance.

An ideal cutting material combines high hardness with good toughness and chemical stability. In particular, hardness and toughness represent opposing properties and there is no single cutting material, which achieves all three conditions simultaneously. In order to merge the mentioned characteristics, wear resistant coatings with tough substrate materials are combined.

A tool coating is a layer with thickness ranging from 2 to 15 μm solidly deposited and bonded to the tool substrate to improve the cutting-tool performance and applied after the tool is shaped. Coatings provide a hard, chemically stable surface and thermal protection to tools, improving their performance during cutting. The effects of coatings are

1. Reduction in friction
2. Reduction in generated heat
3. Reduction in cutting forces.
4. Reduction in the diffusion between the chip and the surface of the tool, especially at higher speeds (the coating acts as a diffusion barrier).
5. Prevention of galling, especially at lower cutting speeds.

OBJECTIVES AND SCOPE OF THE STUDY

Following are objectives of present study-

1. Experimental verification of different coatings to find the suitable coating.
2. To find wear analysis and coefficient of friction for different coating with pin on disc machine.
3. To obtain relation and co-relation between various affecting parameters with the help of regression equation.
4. To increase the tool life by using coating.
5. To do the micro structural study of the specimen.

The scope of work for present study is as follows. The different common materials that are used in the tool for machining operations of the different base work piece materials, the High Speed Steel (HSS) is commonly used tool material and tool life is a very major factor in order to increase the machining life of the tool and to reduce the cost of machining so in order to increase the life of tool the tool should coated with some coating material with different methods, then the coated specimen will be tested on pin on disc

machine by selecting the number if parameter and their levels by Taguchi method of Design Of Experiment (DOE). Properties of coatings used in this study are as follows.

Titanium Nitride (TiN) - General purpose PVD coating that increases hardness and has a high oxidation temperature. This coating works great while cutting or forming with HSS tooling.

Chromium Nitride (CrN) **-** The anti-seizure properties of this coating makes it preferred in situations where BUE is common. HSS or carbide cutting and forming tools will be seen with this almost invisible coating.

Diamond **-** A CVD process that offers the highest performance available in non-ferrous materials is ideal for cutting graphite, MMC (Metal Matrix Composites), high silicon aluminum and many other abrasive materials. Coatings for hard milling, tapping and drilling all vary and are application-specific. Also available are multi-layer coatings that chip to the next layer instead of the tooling substrate, providing a further increase in tool life.

Important properties of these coatings are summarized in Table 1 as follows.

Table 1 – Properties of Various Coatings Used in Present Study

Sr. No.	Parameter	TiN	CrN	DLC
1	Colour	Gold	Grey	Black
2	Hardness [*Hv*]	2400	2700-2900	1500-2400
3	Thickness [μ]	1-7	1-5	1-8
4	Friction	0.55	0.57	0.20
5	Maximum usage temperature (^{o}C)	600	600	650

EXPERIMENTATION

Factorial design and linear regression techniques have been widely used in engineering analysis. These techniques consist of experiments with an objective of acquiring data in a controlled way, executing these experiments in order to obtain information about the behaviour of a given process. This section describes the number of experiments by full factorial design and carried analytical work based on the ANOVA. Necessary details are provided in Table 2. Composition of HSS T-42 is presented in Table 3.

Table – 2 Factors and Their Levels for Experimentation

Factor	**Unit**	**Levels**		
		1	**2**	**3**
Speed	RPM	500	750	1000
Load	Kg	1	3	5
Sliding distance	M	2000	4000	6000
Coating		DLC	CrN	TiN

Table 3 – Composition of HSS T-42

C	1.28	**Cr**	4
Mo	3.3	**W**	9.2
V	3.1	**Co**	9.6
Mn	-	**Si**	-

Trials are conducted by using pin on disk machine (Figure 1) manufactured by Ducom industries Ltd. Banglore.

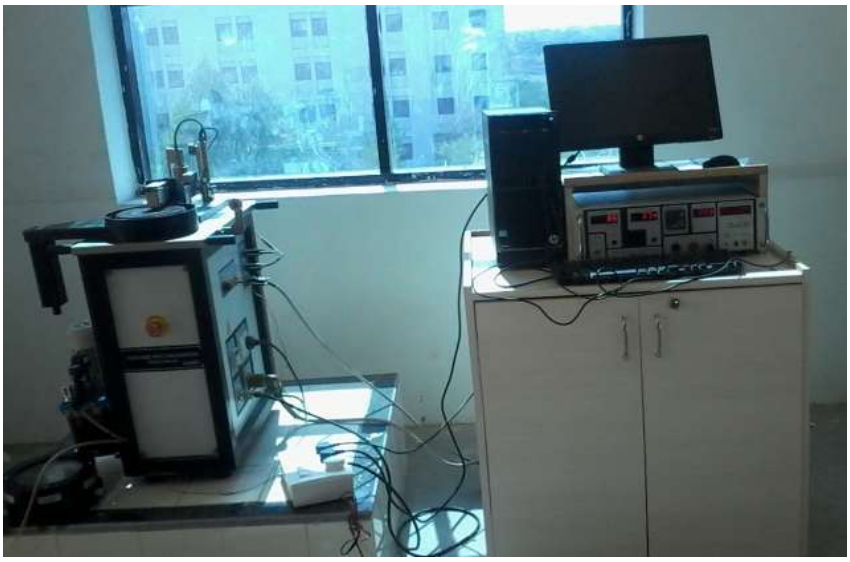

Figure 1 Arrangement of Experimental Setup for Present Study

The base material selected as high speed steel with pins of rounded shape having dimensions as 26 mm in length and 8 mm in diameter as shown in Figure 2.

Figure 2 Base Material Pins.

RESULTS AND DISCUSSION

Taguchi concept of design of experiment is used in present project work, it also found in trials are conducted by using L9 array four factor and three levels for every factor are consider as mention in Table 4 design is performed on basis of 'smaller is better' for both responses such as wear and coefficient of friction (COP). Testing is conducted at room temperature 230C and 40 to 50 % relative humidity. Track diameter (rotational movement) is varied from 80 mm to 140 mm as per requirement. Pin of size (8 mm diameter and 26 mm length) is used to slide against disk made up material EN31 and size (165 mm dia.8 mm thickness) for various combination of factor as for orthogonal array.

The experiments were being carried out as per Taguchi parametric design concepts and an L9 orthogonal array will be used to study the influence of various combination of process parameters. Statistical optimization technique, ANOVA, will be used to determine optimum levels and to find the significance of each process parameter. The results of experiments are presented in Table 3. These results are

obtained from the experimentation of pin at different level of parameters on the pin on disc machine. Load in Kg, Sliding Distance in Km, Speed in RPM, TiN - Titanium Nitride, CrN - Chromium Nitride, DLC - Diamond like Carbon.

These are the reading obtained from the experiments conducted on the pin on disc machine.

Analysis of Variance (ANOVA) is carried out using MINITAB-16 software. The effect of various process parameters on response variables was analysed using analysis of variance (ANOVA) and mean effect plot.

Table 4 – Experimental Results

Expt. No.	SPEED (rpm)	LOAD (kg)	SD (km)	COATING	WEAR	COF
1	500	1	2	TiN	82	0.246
2	500	3	4	TiN	93	0.279
3	500	5	6	TiN	112	0.306
4	750	1	2	TiN	129	0.254
5	750	3	4	TiN	149	0.268
6	750	5	6	TiN	189	0.280
7	1000	1	2	TiN	247	0.115
8	1000	3	4	TiN	240	0.148
9	1000	5	6	TiN	255	0.190
10	500	1	2	CrN	79	0.278
11	500	3	4	CrN	83	0.292
12	500	5	6	CrN	88	0.309
13	750	1	2	CrN	95	0.221
14	750	3	4	CrN	107	0.249
15	750	5	6	CrN	105	0.282
16	1000	1	2	CrN	286	0.136
17	1000	3	4	CrN	270	0.146
18	1000	5	6	CrN	301	0.162
19	500	1	2	DLC	37	0.208
20	500	3	4	DLC	42	0.236
21	500	5	6	DLC	54	0.303
22	750	1	2	DLC	63	0.183
23	750	3	4	DLC	74	0.216
24	750	5	6	DLC	70	0.262
25	1000	1	2	DLC	48	0.202
26	1000	3	4	DLC	52	0.219
27	1000	5	6	DLC	63	0.265

The Figure 3 and 4 shows the main effects plots for wear and coefficient of friction.

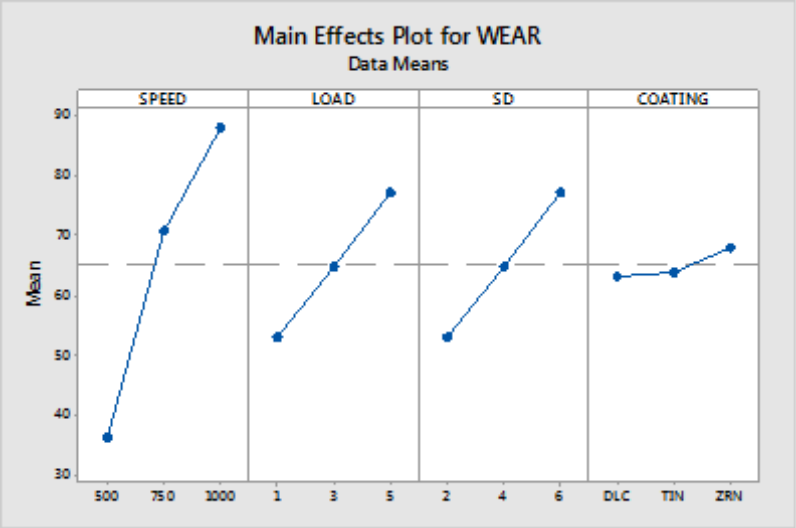

Figure 3 - Main Effects Plot for Wear

Table 5 - Wear Vs Speed, Load, SD, Coating

Sr. No.	Source	DF	Adj. SS	Adj. MS	F-Value	P-Value	% Error
1	Speed (rpm)	1	66248	66248.0	30.08	0.000	36.45
2	Load (kg)	1	1625	1624.5	0.74	0.400	0.34
3	SD (Km)	1	93	93.4	0.04	0.839	0.05
4	Coating	2	67507	33653.6	15.32	0.000	34.14
5	Error	21	46253	2202.5			
6	Total	26	181727				

R-sq = 90.28% R-sq (adj.) = 84.49 %

From the above Table 5 the coefficient of determination is 90.28 hence all data completely fitted.

From the graph of Figure 3, it is clear that as the speed (rpm) and load are increased the wear is also increased, as the sliding distance is increased the wear is increased, and also with the coating the Diamond like carbon coating has lowest wear rate and the higher wear is found with CrN coating, the TiN coating has moderate wear rate.

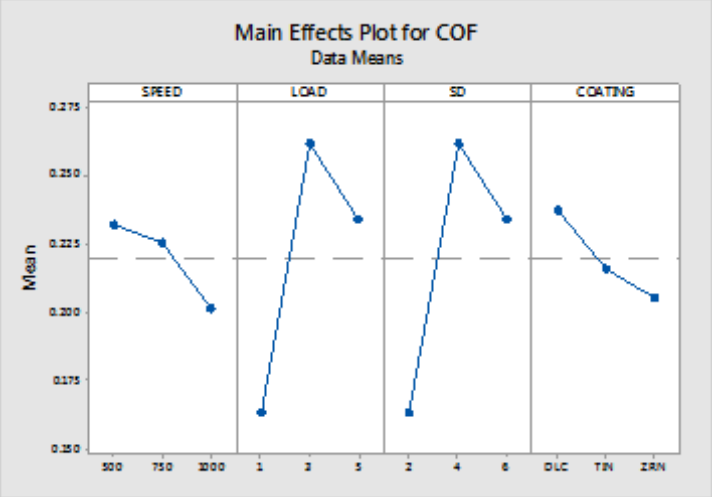

Figure 4 – Main Effects Plot for COF

Table 6 - COF VS Speed, Load, SD, Coating

Sr. No.	Source	DF	Adj SS	Adj MS	F-Value	P-Value	Error(%)
1	Speed	2	0.044698	0.022339	18.94	0.000	0.55
2	Load	2	0.015132	0.007566	6.41	0.008	18.64
3	Sd	2	0.000061	0.000030	0.03	0.975	0.075
4	Coating	2	0.000015	0.000007	0.01	0.994	0.018
5	Error	18	0.021240	0.001118			26.17
6	Total	26	0.081145				

R-sq = 92.17%, R – sq (adj.) = 84.15%

From the above Table 6, the coefficient of determination is 92.17, hence all data completely fitted.

The above graph shows that the coefficient of friction is decreased with increased in speed, as the load and sliding distance increased the value of COF is increased up to certain value then decreased, for the different coatings the value of COF is lower for CrN and Higher for DLC coating.

REGRESSION EQUATION

The regression equation for the different parameter is given as

COATING DLC

Wear = -144.9 + 0.2427 Speed + 4.75 Load + 1.14 Sliding Distance

COF = 0.3306 - 0.000193 Speed + 0.01442 Load + 0.00092 Sliding Distance

TiN

Wear = -34.6 + 0.2427 Speed + 4.75 Load + 1.14 Sliding Distance

COF = 0.3299 - 0.000193 Speed + 0.01442 Load + 0.00092 Sliding Distance

CrN

Wear = - 43.7 + 0.2427 Speed + 4.75 Load + 1.14 Sliding Distance SD

COF = 0.3288 - 0.000193 Speed + 0.01442 Load + 0.00092 Sliding Distance

From the above three regression equation are for calculating the wear rate and coefficient of friction for different coatings with respect to the different considered parameters for experimentation and the values obtained from regression equation are approximately equal.

MICROSTRUCTURAL TESTING

The samples were tested at Fan services Nashik and the results are noted as below with coated sample specimen with Unetched Condition and AT 100/ 500 X Magnification.

1. TiN

Surface showing golden yellow colour, Surface morphology, showing little porosity and equiaxed fine grains uniformly distributed.

Figure 5 Microstructure of TiN

2. CrN

Surface is showing mirror smooth black colour. Surface morphology showing little porosity and banded Carbides visible. Otherwise fine grain Carbides is seen.

Figure 6 Microstructure of CrN

3. DLC

Nodules of SP3 banded Carbon atoms in rolled direction seen. The grains are so

small that the surface appears mirror smooth to the eye.

Figure 7 Microstructure of DLC

CONCLUSION

The experiments are conducted on Pin on disc machine for that the parameters and there levels are selected as per Taguchi method.

From the above results it is clear that the diamond like carbon coating has low wear rate and it is suitable coating for high speed steel tool to increase the life of tool.

The relation between different parameters like wear, coefficient of friction with speed load and sliding distance are found by means of regression equation.

From the microstructural analysis it is clear that the samples were properly coated with the TiN as compare to CrN, DLC.

REFERENCES

I. Miroslav Piska, Petra Sliwkova, Surface Parameters, Tribological Tests and Cutting Performance of Coated HSS Taps, 25th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2015, pp.125-134.

II. Suraj R. Jadhav, Aamir M. Shaikh, Study & Performance of Coated Cutting Tool , International Journal of Engineering, Business and Enterprise Applications (IJEBEA), ISSN (Print): 2279-0020 , 2015, pp.99-104.

III. B. K_l_nc, O. Cegil, S. Sen, U. Sen, Wear Behavior of TiAlN and CrAlN Coatings Deposited by TRD Process on AISI D2 Steel, Proceedings of the 3rd International Congress, Vol. 125 , 2014, pp. 362 - 364.

IV. R.Venkatesh, Dr.Vaddi seahagiri Rao, Dr.N.Arunkumar,Sunil Biswas ,R.Shoban kumar, Wear Analysis on Silicon carbide coated HSS Pin on SS Disc Substrate, 2nd International Conference on Nanomaterials and Technologies, 2014 pp.644-650.

V. Wringle Joseph Kuttianimattom, Peter Jose, Property Analysis of PVD Deposited DLC, TiAlN,

CrAlN, TiN Coating on Gray Cast Iron, ISSN 2319-3182, Volume -3, Issue-3, 2014, pp.54-57.

VI. M.R. Ibrahim, A.R.Abd.Kadir, M. S. Omar, S.Sulaiman and M.H.Osman, Optimization of Parameter for HSS Tool Wear by using Taguchi Method and Finite Element Method, Applied Mechanics and Materials Vol 315 , 2013, pp 151-155.

VII. Natalia L. Cadena , Rodrigo Cue-Sampedro, Héctor R. Siller, Ana M. Arizmendi-Morquecho, Carlos I. Rivera-Solorio and Santiago Di-Nardo, Study of PVD AlCrN Coating for Reducing Carbide Cutting Tool Deterioration in the Machining of Titanium Alloys, ISSN 1996-1944, 2013, pp.2143-2154.

VIII. R K Upadhyay, L A Kumara swamidhas, Friction Behavior of Tin, CrALN Coating On AISI 4320 Steel Substrate, Int. J. Mech. Eng. & Rob., 2013, pp. 107-109.

IX. Willey Y. H. Liew, Jester Ling Lih Jie, Lim Yee Yan, Jedol Dayou, C.S. Sipaut, Mohd Faizah Bin Madlan, Frictional and wear behaviour of AlCrN, TiN, TiAlN single-layer coatings, and TiAlN/AlCrN, AlN/TiN nano-multilayer coatings in dry sliding, The Malaysian International Tribology Conference, 2013, pp.512-517.

X. W.Y.H. Liew, Sebastian Dayou, Mohd. Azlan Bin Ismail, Nancy J. Siambun and Jedol Dayou, Dry Sliding Behaviour of AlCrN and TiN Coatings, Advanced Materials Research Vol. 576 , 2012, pp 559-564.

XI. V. Braic, C.N. Zoita, M. Balaceanu, A. Kiss, A. Vladescu, A. Popescu, M. Braic, TiAlN/TiAlZrN multilayered hard coatings for enhanced performance of HSS drilling tools, Surface & Coatings Technology, 2010, pp. 1925–1928

XII. Dae-Hyun CHO, Young-Ze LEE, Evaluation of ring surfaces with several coatings for friction, wear and scuffing life, 2009, pp.992-996.

XIII. G.G. Fuentes, R. Rodriguez, J.C. Avelar-Batista, J. Housden, F. Montal´a, L.J. Carreras, A.B. Crist´obal, J.J. Damborenea, T.J. Tate, Recent advances in the chromium nitride PVD process for forming and machining surface protection, 2005, pp.415–421.