MECHANICAL PROPERTIES ANALYSIS OF HARD COATED CUTTING TOOL

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ABSTRACT

All high-speed tool steels have many similar mechanical and physical characteristics the properties may vary widely due to changes in chemical composition. Basically, the most important property of a high-speed tool steel is its cutting ability. M2 grade is a medium alloy high speed steel which has a good machinability and a good performance and used in a wide variety of application. The aim with this is to extend the understanding on how the mechanical properties & cutting performance are affected by cutting tool and workpiece during operation. Thin Films of TiAlN and CrN have been deposited on HSS M2 grade cutting tool substrate using Cathodic Arc Evaporation (CAE-PVD) Method. Comparison thickness, Surface roughness, Wear resistance, Cutting force, Hardness, to measure between two coating material also with uncoated tool.

Keyword:- *HSS, CrN & TiAlN Coatings, Wear, Cutting force*.

INTRODUCATION

Coating is most necessary and basic feature of any parts now a days. By applying the coating on the substrate material the work of the parts increase. Coating in thin and thick film mostly using. A thin film through to protect the surface of metal and it improve the mechanical properties like hardness, corrosion etc., and also improved the most tribological properties wear resistance for cutting tools, thermal stability, electrical resistance, aesthetic look, improve the surface quality etc. Different methods of applying either metallic coating or nonmetallic coating. For other method for the stability of metal surface. A better coating selection for substrate materials to give the better tool life, increase cutting performance, decrease the heat for various application and improve the aesthetic look for various appliance. The cutting operation in to protect the coating material on cutting tools to reduce the crater wear, abrasive, and adhesion at dry and wet condition and high speed machining. A modern coating materials are use to decrease the friction between tool and workpiece.

The commercial drills was attributed to the role of the plasma nitriding in improving the TiN-coating adhesion, and, thus, increasing the wear resistance of the coating.[(1)] A part from the coating type and substrate, the tool geometry and cutting conditions have been found to be important factors affecting the quantitative reductions of cutting forces by tool hard surface coatings.[(2)] Hard coating is apply on materials and decreased the friction, erosion. and build up edge. Hard Coating develop decrease the roughness and increase the surface texture develop during the component moves and injection force of mold to shooter cycle times. Minor finish or major finish, repolishing all thing to depends coating materials. Good Coating selection through improve the productivity. The tool geometry as well as mechanics of chip arrangement are complex, such as gear shaping cutters, helical twist drills, hobs, reamers, broaches, form tools etc. High presentation Shapers, Gear Cutting Hobs, Bevel tools, Milling cutters, of all kinds of very much stressed twist bits in addition to taps, shaped trim blades. For working elevated strength materials and broaches. Impact tools as well as those used designed for working timber. Cold forming tools such as dies as well as punches for chilly extrusion along with cutting and very well cutting deal with. Coating is reduce wear and useful in dry condition so not use lubricants. Solve the problem in Tribometer at 200ºC and 250ºC by coating.

EXPERIMENTAL DETAILS

Substrate Material

In this work, we have studied on HSS M2 grade cutting tools and single layer coating on substrate materials by Cathodic arc deposition(CAE) The chemical composition of HSS is (C0.75%, Si0.34%, Cr4.290%, M5.6%, V1.760%). Many types of high speed steel materials like molybdenum and tungsten grades. This material goods allows HSS to cut faster than high carbon strengthen, therefore the name speedy steel. At area temperature, in their normally suggested heat behavior, HSS rating usually present high hardness (above HRC60) in addition to scratch resistance (normally linked to tungsten along with vanadium comfortable repeatedly used in HSS) compared with common carbon along with device steels. Ultra sonic cleaning process using before the deposited on substrate materials.

Coating Materials

Titanium aluminum nitride or else aluminum titanium nitride intended for **(** aluminum stuffing higher 50 at.%) position for a collection of met stable solid covering consisting of the metallic fundamentals aluminum as well as titanium with nitrogen. Chromium nitride is a chemical compound of chromium and nitrogen through the method CrN. It is very complex, as well as is enormously resistant to decomposition. This coating for good choice form tooling providing improved adhesive strength to the substrate maintain the wear resistance low friction layer when forming pressure is high.

Cathodic Arc Deposition Technique

The cathode spot is the extremely small and hot cathodic root of a high current low voltage arc. it melts and evaporation the cathode material forming a kind of micro crucible which has a diameter of about 1µm to 20µm and a live time of the order. When it extinguishes, a new micro curable is formed near by the former one. This way, the cathode surface leaving irregular strings of small craters. The machine is equipped with eight cathodic semicircle sources. When the arc current is increased a second, third etc. arc splits off. The spot velocity of the total number of micro droplets shows a maximum at an angle, which seems to be somewhere between 20º and 60º to the plane of the cathode depending on the experimental conditions. The mechanism is equipped through 6 cathodic arc sources. Nitrogen is supplied by a flow into the deposition chamber. The temperature of the deposition on the substrate material should be started from 25°C to 750°C. Deposited film on the substrate material reveals the TiAlN and CrN Coated components on HSS M2 grade cutting tool substrate. the nitrogen deposition pressure applied on to the coating material was 3.5Pa. This technique through bettered hardness and wear resistance, The use of such coatings is aimed at improve efficiency through bettered performance and highly component life.

Vicker Hardness Test

Vickers test is completed with different forces as well as indenters. The square-base pyramidal gemstone indenter is actually forced within a established load which range from 1kgf to be able to 120 kgf into your material to get tested. As soon as the forces have reached a static as well as equilibrium condition and further penetration ends, the pressure remains requested for a particular time (10 to be able to 15s for typical test times) and is then taken away. T. This Vickers indenter offers included face angles regarding 136° , and also the Vickers hardness number (HV) is actually computer from the following equation,

$$HV = \frac{2PSin(136/2)}{d^2} = \frac{1.8544P}{d^2}$$

where P = Indentation load, kgf d = Diagonal of indentation, mm. HV= Hardness Symbol. α = face angle of diamond = 136°. Vickers numbers to get a 1 kgf load, so it is not important to calculate every single test effect. The two coating hardness are same , CrN and TiAlN 800 HV by Vicker hardness tester. A value of 800 HV10 represents Vickers hardness of 800 made with a force of 10 kgf applied for 10 to15s. 800 HV10/20 represents Vickers hardness of 800 made with a force of 10 kgf applied for 20s. Any Vickers hardness tester needs to be verified to begin with of about three forces such as the forces chosen for examining.(12)

Coating Thickness

The Coating thickness of Coating TiAlN and CrN on HSS M2 Grade using Digital Coating thickness Gauging system. A Digital Coating thickness gauge is very easy to work, accurate, reliable, rugged, efficient, powerful etc. This Coating thickness gauge do the High and low reading limit indicators, Measurement capability to ±1%, Can be used in accordance with National & International Standards, Increased reading resolution for thin coatings, Measures accurately on smooth, rough, thin and curved surfaces, Compatible with ElcoMaster™ 2.0 software.

Sample Description	Average Coating Thickness in (µm)
HSS M2 - TiAlN Cutting tool	23
HSS M2 - CrN Cutting tool	32

Tribology

This specific test approach describes any laboratory technique of determining the actual wear involving materials during sliding using a pin-on-disk equipment. Materials are usually tested within pairs beneath nominally non-abrasive disorders. The principal regions of experimental focus in using this type of apparatus to be able to measure wear are referred to. The coefficient involving friction are often determined. resistant to the disk at a specified weight usually by using an equip or lever and also attached weight loads. Other running methods are used, for example, hydraulic or pneumatic. Disc of speed 500rpm, 1000rpm, 1500rpm with 50N load apply on substrate materials uncoated and coated cutting tools in room temperature by dry lubricant condition at a continues 15minutes. The Track diameter 80mm and applying load 50N.

Force measurement

These are consider superior to mechanical dynamometer and are most widely used.(13) A typical cantilever type strain gauge turning dynamometer is shown in Fig.1. The device works in conjunction with a Wheatstone flow bridge circuit. The force being measured are Pz and P_X.

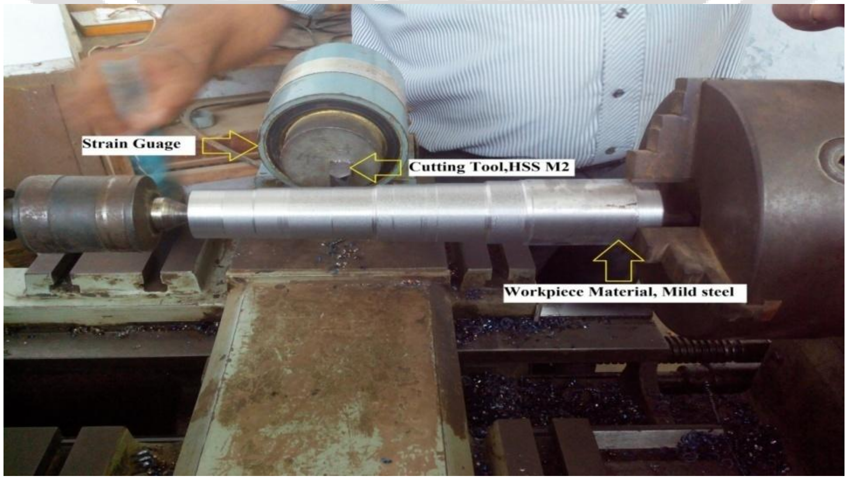


Figure 1:- Experimental Setup of Cutting Force And Feed Force Measure
By Strain Gauge Indicator

Workpiece material is here the mild steel. Work piece of standard dimensions was used for machining work piece diameter: 50mm, work piece length 250mm. HSS M2 cutting tools are using , uncoated and coated cutting tools. A coated cutting tools are CrN and TiAlN. The processes parameters are, rack angle 0º,feed rate is 0.05, 0.1 and 0.23 mm/rev, depth of cut 1.0, 0.75 and 0.5mm, and this condition was in dry lubrication condition

RESULT AND DISCUSION

Wear

- Chart of uncoated and Coated cutting tool Frictional force and Time at 500 rpm, 1000 rpm & 1500 rpm.

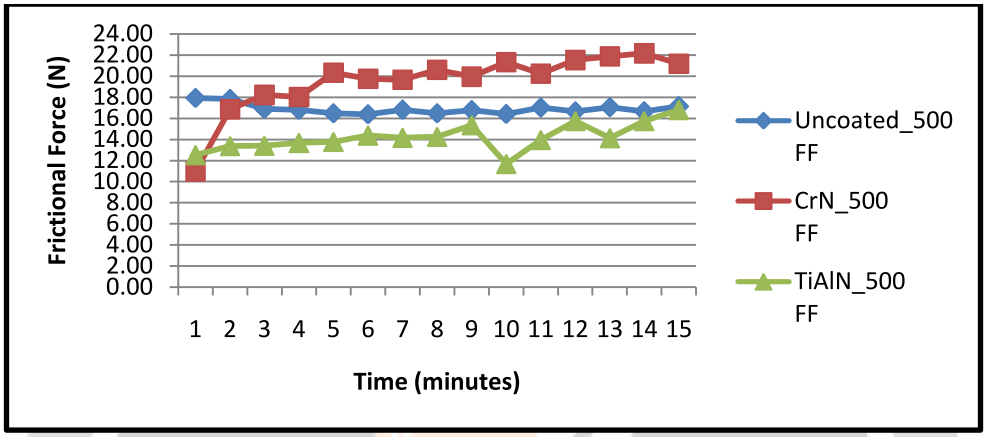


Chart 1

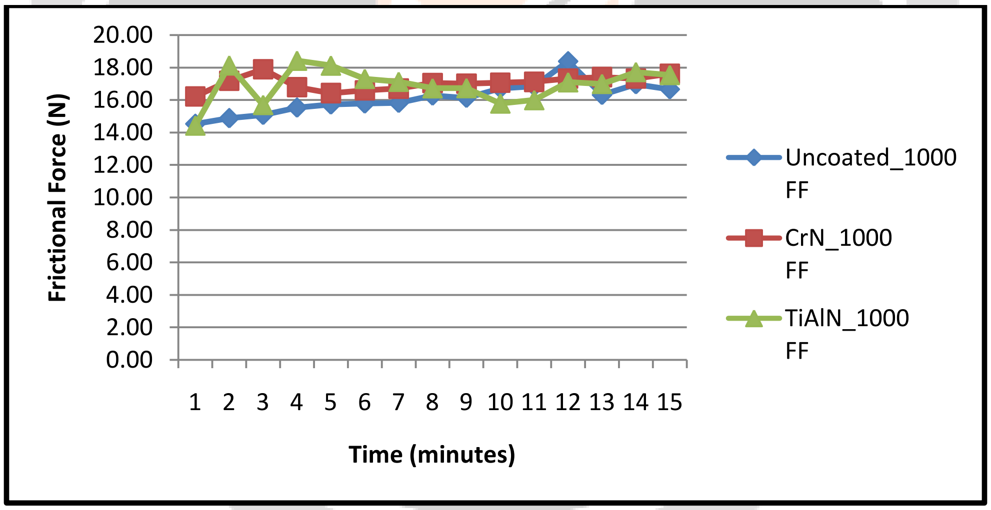


Chart 2

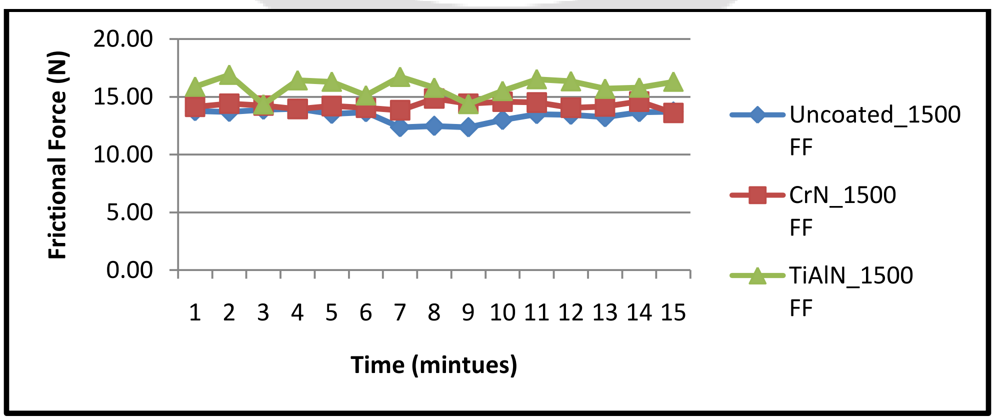


Chart 3

- Chart of uncoated and Coated cutting tool Wear and Time at 500 rpm, 1000 rpm & 1500 rpm.

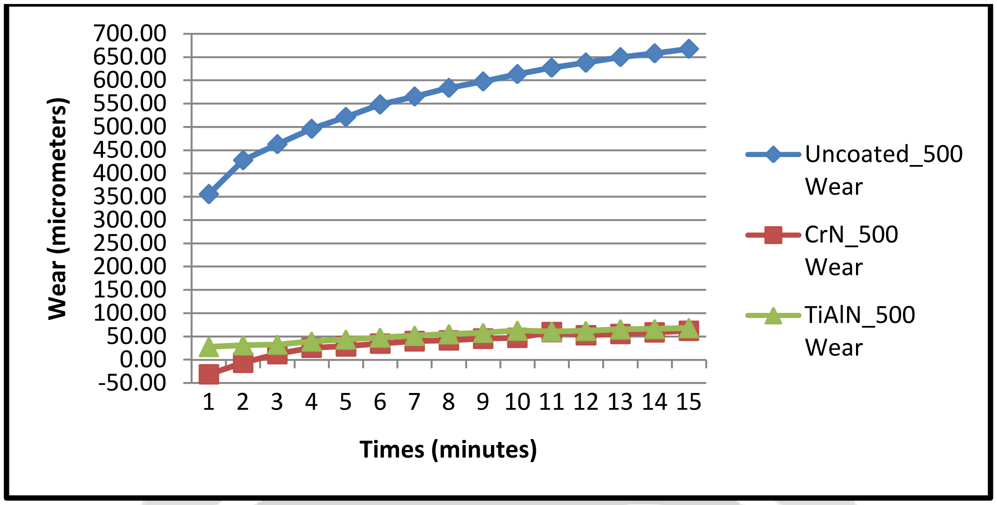


Chart 4

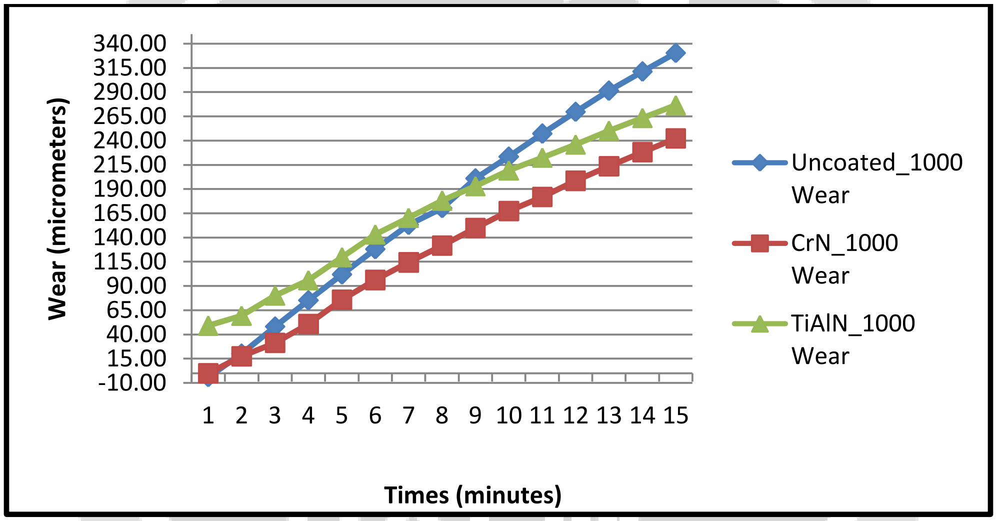


Chart 5

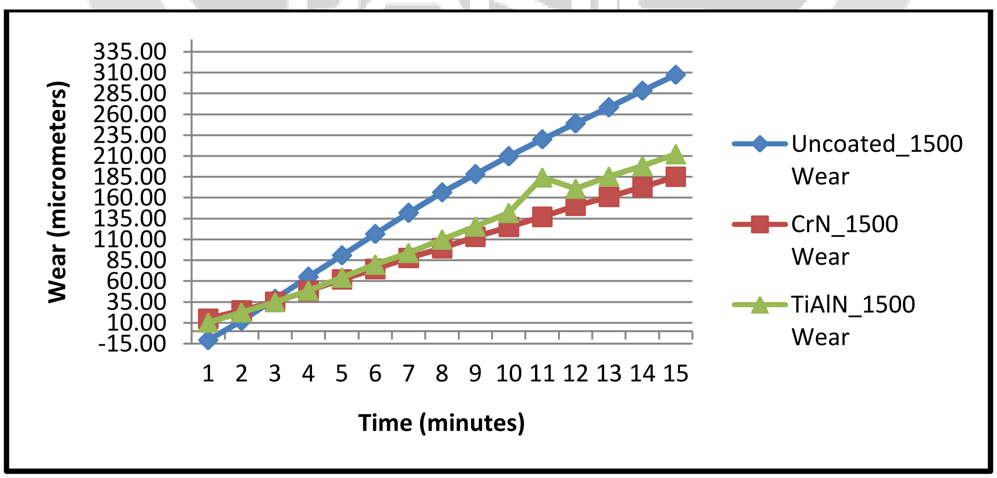


Chart 6

- Chart of Coefficient of Friction and Time at 500 rpm, 1000 rpm & 1500 rpm.

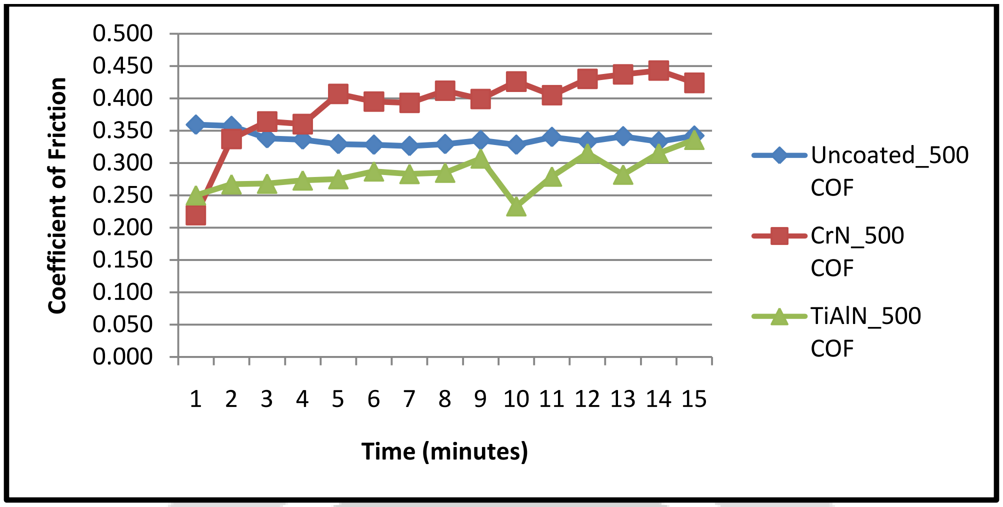


Chart 7

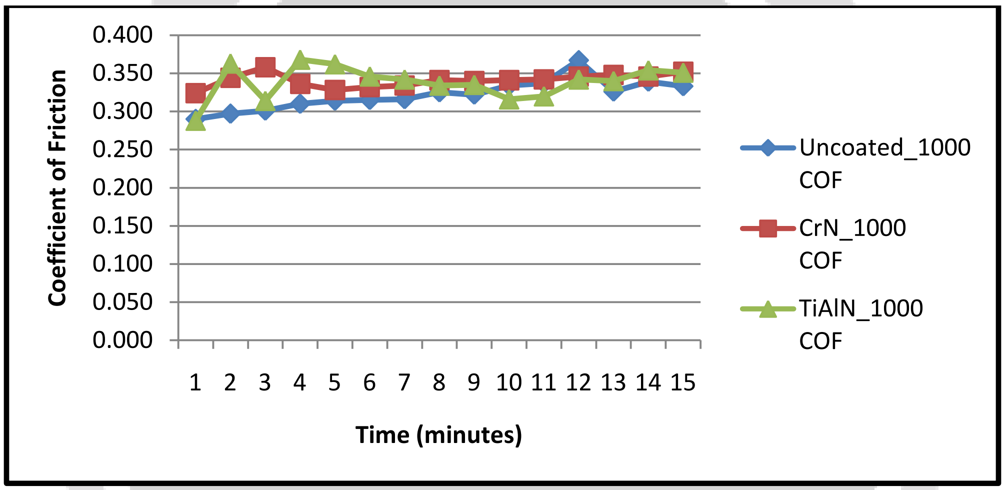


Chart 8

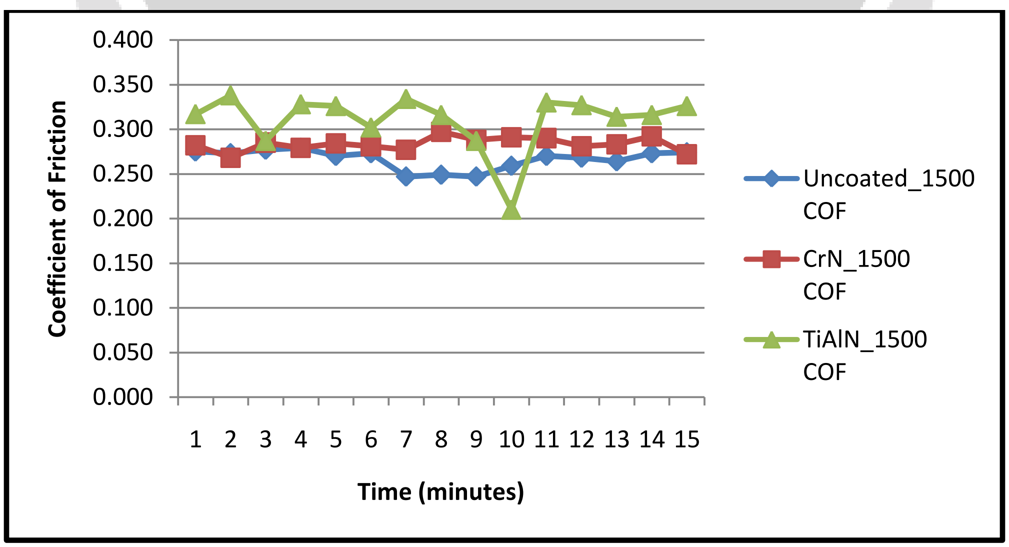
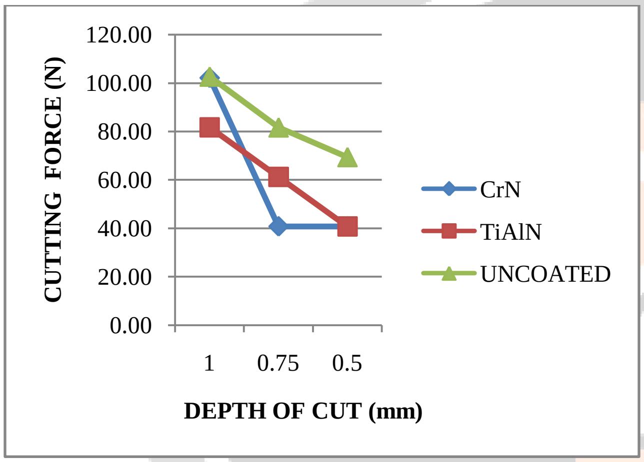


Chart 9

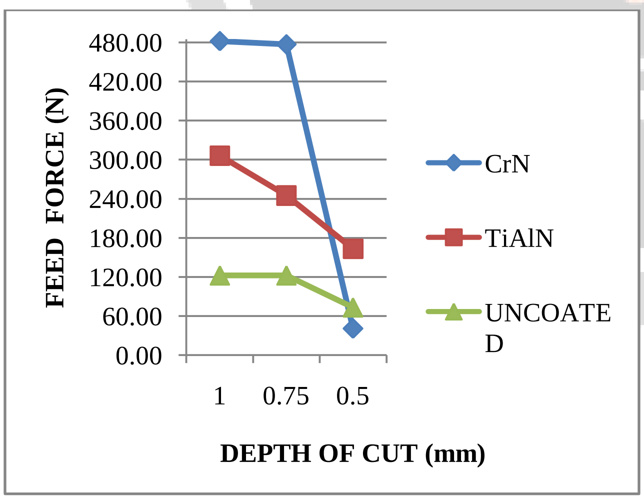
Showing the chart no. 1,2and 3 in the three different friction forces versus time line chart CrN_500FF at initially stage value was rapidly raise and last settled 17.12N. TiAlN_500FF was constantly raised but forces was suddenly decrease at 10min time. Uncoated value was constantly same. the other side CrN_1000FF and TiAlN _1000FF was both initially beginning soaring. But after the both forces was persistently same. And Uncoated_1000FF was suddenly at 12min goes down up to 16.30N. Showing the chart 4,5 and 6 in the Uncoated_500wear was started 355.40micrometers follow by value was constantly grow up and settled top of point 667micrometers. Moreover CrN_500wear start of negative point later than the value was persistently set on positive point respectively value is -30.95 and 62.30micrometers. TiAlN _1000 wear and Uncoated_1000wear was started respectively -4.07,-0.10 and 49.03 at same 1min same time follow by constantly increase reach up to respectively 330.33, 242.29 and 276.61 at the end of 15min. Showing the chart 7, 8 and 9 in the CrN_1000 COF and Uncoated_1000COF was similar grow up .CrN_1500 COF and Uncoated_1500COF notice that starting and ending value both are same and between them value was fluctuated.

Force Measurement



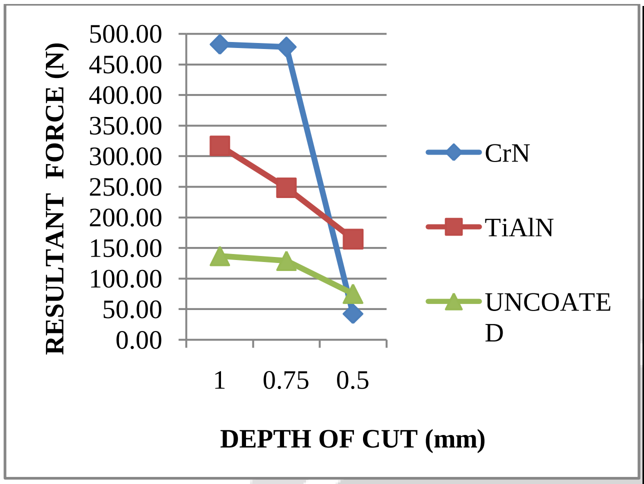
	DEPTH OF CUT (mm)	CUTTING FORCE PU1(N)		
		CrN	TiAlN	UNCOATED
rpm=384 & f=0.2	1	**102.08**	81.67	102.68
	0.75	40.83	61.25	81.67
	0.5	40.83	40.83	69.42

Chart 1and Table 1:- Cutting Force Vs Depth of cut (o/p maximum cutting force)



	DEPTH OF CUT (mm)	FEED FORCE PU2(N)		
		CrN	TiAlN	UNCOATED
rpm=384 & f=0.1	1	**481.83**	306.25	122.50
	0.75	477.15	245.00	122.50
	0.5	40.83	163.33	73.50

Chart 2 and Table 2:- Feed Force Vs Depth of cut (o/p maximum feed force)



	DEPTH OF CUT (mm)	RESULTANT FORCE (N)		
		CrN	TiAlN	UNCOATED
rpm=384 & f=0.1	1	**482.46**	316.95	136.96
	0.75	478.19	248.38	129.13
	0.5	42.63	164.60	75.29

Chart 3 and Table 3:- Resultant Force Vs Depth of cut (o/p maximum resultant force)

Depth of cut verses Cutting force in chart and table1 are show in the maximum cutting force 102.08 feed 0.2mm/rev ,depth of cut1mm at rpm384m/min. In this table all value are decrease and same as the cutting force of uncoated cutting tool at same feed. depth of cut and rpm. but the value of TiAlN coated cutting tool is less between others tools. The second chart is same but depth of cut verses feed force. In this chart the TiAlN value is higher than uncoated cutting too but lower than CrN coated cutting tools. The all values of TiAlN are decrease at different parameters. The values of CrN coated cutting tool is suddenly decrease at depth of cut0.5mm. Same as the all the CrN value are suddenly decrease at different feed and depth of cut. Showing the chart3 and table3 in the resultant verse depth of cut at feed384mm/rev and rpm384m/min. In this chart the value of CrN is higher than all cutting tools. The value of CrN is 482.46N and all values and condition same as above charts.

COCLUSION

The hardness value of uncoated 60HRC and coated cutting tools (CrN 800HV and TiAlN 800HV) by Vicker hardness tester. The coating thickness of coated cutting tools CrN and TiAlN is 32µm and 23µm respectively by digital coating thickness gauge. Tribometer through measure the wear, starting rpm 500 to high wear rate and suddenly increase wear rate at different rpm of uncoated coated cutting tool. The low wear rate of CrN coated cutting tool at 500,1000 and 1500 rpm with compare other coated and uncoated cutting tools. The wear rate is some high of TiAlN coated cutting tool to other coated cutting tool and uncoated cutting tool. The final result is CrN coated cutting better wear resistance. The final result of Cutting and feed force related the CrN coated cutting tool is better than other coated and uncoated cutting tools. Because the value of TiAlN coated cutting tool is high to compare CrN coated cutting tool and the tip of uncoated cutting tools is blunt ate higher rpm.

REFERENCES

(1) J. Nickel ,A.N. Shuaib, B.S. Yilbas ,S.M. Nizam, "Evaluation of the wear of plasma-nitrided and TiN-coated HSS drills using conventional and Micro-PIXE techniques", Wear, 2000, 239, 155–167

(2) J. Wang, “The effect of the multi-layer surface coating of carbide inserts on the cutting forces in turning operations”, Materials Processing Technology, 2000,97, 114-119

(3) V. Fox, A. Jones, N.M. Renevier , D.G. Teer, “Hard lubricating coatings for cutting and forming tools and mechanical components”, Surface and Coatings Technology, 2000, 125, 347–353

(4) G.S. Fox-Rabinovich, N.A. Bushe, A.I. Kovalev c, S.N. Korshunov, L.Sh. Shuster, G.K. Dosbaeva, "Impact of ion modification of HSS surfaces on the wear resistance of cutting tools with surface engineered coatings" Wear, 2001,249,1051–1058.

(5) J. Richter, J. Cwajna , J. Szala, " Quantitative assessment of new high speed steel substrate and PVD wear resistant coatings", Materials Characterization,2001, 46,137– 142

(6) L.A. Dobrza´nskia, K. Gołombeka, J. Kopaˇc, M. Sokovi´c, "Effect ofdepositing the hard surface coatings on properties of the selected cemented carbides and tool cermets", Materials Processing Technology, 2004, 157–158,304–311

(7) G.S. Fox-Rabinovicha, S.C. Veldhuisa, G.C. Weatherlya, A.I. Kovalevb,S.N.Korshunovc,V.N.cvortsovd, G.K.Dosbaevaa,L.Sh.Shustere, D.L. Wainsteinb, "Improvement of duplex PVD coatings for HSS cutting tools by ion mixing", Surface & Coatings Technology, 2004, 187, 230– 237

(8) A.E. Reiter , B. Brunner, M. Ante , J. Rechberger, " Investigation of several PVD coatings for blind hole tapping in austenitic stainless steel", Surface &Coatings Technology, 2006, 200, 5532 – 5541

(9) RecepYigit , Erdal Celik , Fehim Findik , Sakip Koksal, "Tool life performance of multilayer hard coatings produced by HTCVD for machining of nodular cast iron", Refractory Metals & Hard Materials, 2008, 26, 514–524

(10) J. Gertha, M. Larssonb, U.Wiklunda, F. Riddara, S.Hogmarka, "On the wear of PVD-coated HSS hobs in dry gear cutting", Wear, 2009, 266,444–452

(11) M. Sokovi ´c, B. Bariˇsi ´c, S. Sladi´, "Model of quality management of hard coatings on ceramic cutting tools", Materials Processing Technology, (2009), 209, 4207–4216

(12) F. Qin a, Y.K. Chou ,D. Nolen , R.G. Thompson, "Coating thickness effects on diamond coated cutting tools", Surface & Coatings Technology, 2009, 204, 1056–1060

(13) M.A. ElHakim, M.D.Abad ,M.M.Abdelhameed , M.A.Shalaby ,S.C.Veldhuis, " Wear behavior of some cutting tool materials in hard turning of HSS", Tribology International , 2011, 44, 1174–1181

(14) A.S.H. Basari,A.S.M. Jaya, M.R. Muhamad, M.N.A. Rahman, S.Z.M. Hashim, H. Haron, "Application of ANFIS in predicting TiAlN coatings flank wear", International Conference on Computational Intelligence, Modeling & Simulation, 2011

(15) D. Jakubéczyová, P. Hvizdoˇs, M. Selecká,"Investigation of thin layers deposited by two PVD techniques on high speed steel produced by powder metallurgy", Applied Surface Science, 2012, 258, 5105–5110