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ORIGINAL ARTICLE

Performance And Evaluation Of Piercing Punch Coated With TiAlN

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ABSTRACT
Nano coatings [vacuum heat treatment followed by physical vapour deposition _PVD. Coating] have been given a lot of interest as surface treatment for forming, extrusion dies and cutting tools in recent years. The advantage, as compared to conventional PVD coating, is higher substrate hardness due to the hardening prior to the PVD coating. In this paper, the present investigation is aimed at studying the effect of nano treatment as compared between uncoated and PVD coating respectively, for cold piercing punches. The test specimen [TiN and TiAlN, M2 steel [molybdenum high speed steel]] performance was compared and their productivity and life time were found out .Wear tests were undertaken using a piercing tool. Prior to wear testing, possible causes for wear in piercing tool were analyzed; coating properties were evaluated by surface roughness, hardness and residual stress measurements. Wear tests indicated that a PVD coating of TiN reduced the wear rate by 2.58 times compared with uncoated hardened M2 steel piercing punch and PVD coating of TiAlN reduced the wear rate by 4.8 times compared with PVD coating of TiN. TiAlN was shown to be the most wear-resistant of the tested coatings.
Keywords: Nano coating; Piercing punch; Wear Test

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INTRODUCTION

During cold piercing operation in a forging firm, there is a huge amount of wear observed in the punches. In ancient years punch material used as hardened alloy steel having a hardness of 58 – 60 HRC, which gives the life of 1500 No's per punch. Further improvement the punch material had been changed as hardened Molybdenum high speed tool steel which gives the punch life of 2400 No's per punch.

Piercing punch wear is the result of load, friction, misalignment, cutting clearance and high Temperature between the cutting edge and the work piece. Several wear mechanisms can occur during metal cutting: adhesive wear, abrasive wear, diffusion wear, oxidation wear, and fatigue wear.

In this project we are further enhanced the piercing punch life through PVD coating process. This is based on the several surface coating techniques, such as chemical vapour deposition, physical vapour deposition and thermal spraying, have seen considerable development in recent years. The advantage with PVD is, foremost, the relatively low deposition temperature 200– 500°C.There are many reports of excellent results in industrial applications where friction and wear have been controlled.

PVD (Physical Vapour Deposition) methods enable to form coatings with high hardness, high wear resistance and chemical stability. Importantly, the quality of thin coatings depends on preparation of steel substrate and technological parameters of the PVD process.

We studied the influences of PVD coatings on M2 tool steel life in continuous and interrupted piercing. Monolayers of TiN and TiAlN thin films were coated on the M2 piercing punch. It was stated that in term of the punch life.

Tool life enhancement with PVD applied Titanium Aluminum nitride coating Namely Futura Nano for cemented carbide insert is investigated. It is found that this coating performs95% better in tool wear than Tin coated carbide tool & 33% more depth of cut and can attain higher cutting speed due to better thermal resistance of the coated inserts [1].The Wear experiments in the range of 25-600°c have been conducted on samples with different conditions coated with TiN and TiAlN futura deposited industrially at Balzers by means of PVD[2].

The results indicate that coating the tool steel substrate with these two films give rise to an improvement of 99 %(TiAlN) in the wear behavior at the test temperature of 300°c in comparison with the un coated substrate the coated system with a TiAlN coating displayed a better than that shown by the system with a TiN coating[2].

Tests were carried out on ceramic inserts, uncoated and PVD coated, with hard wear resistant coatings composed of TiN, (TiAlN). In the case of a coated cutting tool, it is almost impossible to conduct direct research on events occurring within the coating surface during the cutting process itself [3].Three types of coatings, TiN, TiAlN, and ZrN, coated by PVD process, were investigated. The TiN coating was selected because it is the most popular coating in the TiAlN coating is recommended by many manufactures and handbooks. TiAlN is harder than Tin, The performance of ZrN coating has not been well studied compared to the TiN and TiAlN coatings. The TiN and TiAlN coatings provided significant improvement in tool life. Cutting tool wear is the result of load, friction, and high temperature between the cutting edge and the work piece. Coated tools can produce high wear resistance on the surface with high toughness in the substrate material. Properly applied coatings increase the surface hardness of cutting tools at high cutting temperatures thus reducing tool wear. The high lubricity of most coatings reduces the coefficient of friction between the cutting tool and the work piece, which also reduces cutting temperature while coating increases initial cost, the benefits of coatings are often more than their cost [4].

The micro-hardness and adhesion properties of the different treatments have been evaluated at different load conditions and confronting the hardness vs load profiles. The tribological behavior of the different treatments has been tested in dry conditions in alternate pin-on-flat configuration. The standalone PVD coatings showed a limited tribological resistance due to the low hardness of the substrate, which resulted in fractures and delamination [5]

The combined effects of the noble, low miscibility metals, Cu and Ag, on the nanostructure and mechanical properties of nitrogen-containing Cr coatings, CrCuAgN coatings were prepared using unbalanced magnetron sputtering. A coating with moderately high hardness of 14.1 GPa and H/E ratio of 0.072, with combined Cu^{+} Ag concentration approaching 15 at.% was obtained, which could be promising in prolonging the lifetime of solid-lubrication tribological coatings.[6]

The coatings studied for their long term stability and found to be stable upto500 °C, although considerable change in optical properties was observed on increasing the temperature 600 °C. [7]

The PVD process parameters play an important role in achieving better coating performance. This proposed study optimizes the PVD process parameters by Taguchi-GA (Genetic Algorithm) method. The parameters such as type of gas, chamber pressure and power input of the PVD process can be optimized to get higher micro hardness and lower wear rate. The type of wear was observed using SEM (Scanning Electron Microscope) microstructures [8]

Machining of Nimonic C-263 has challenging task owing to its hot strength, low thermal conductivity, tendency to work harden and affinity towards tool materials. Although coated tools have been used to overcome some of these challenges, selection of coated tool with appropriate deposition technique is of immense significance. Decrease in surface roughness (74.3 %), cutting force (6.3%), temperature (13.4 %) and chip reduction coefficient (22 %) with PVD coated tool consisting of alternate layers of TiN and TiAlN over its CVD coated counterpart with TiCN/Al2O3 coating in bilayer configuration [9]

PVD coating performed by several methods: Arc, Sputtering, Vacuum evaporation, Cathode sputtering, Magnetron sputtering. By coating of textile materials it is possible to made new materials with specific properties like fabric electrically and thermally conductive, fabric that filter bacteria and viruses, fabric which gives tires the new features in form of embedded sensors.[10]

The properties of the tribo films management the general performance and therefore the similarity between them, in spite of wire material, is that the reason for the similar contact resistance. The Ti–Ni–C coating wears least on the silver–graphite. Each coatings degrade and wear off throughout testing, exposing the steel substrate. The steel itself conjointly wears, though not at a rate excluding it as a potential wire material. None of the 3 surfaces totally displaces wear to the ring solely. Considering the performance of the uncoated steel wire, coatings can't be driven on behalf of either improved electrical performance or wire protection [11]

WORK PIECE

To analyze the wear phenomenon of coated and uncoated punches in cold piercing operation the work piece was C45 medium carbon steel with hardness 22HRC.The chemical composition of the work piece is listed in **Table 1.1.**

Carbon	= 0.42 ~ 0.5
Manganese	= 0.5 ~ 0.8
Phosphorus	= 0.035 max
Sulfur	= 0.035 max
Silicon	= 0.40 max
Nickel	= 0.40 max

Table: 1.1 Work piece chemical compositions

Cutting force & press force

Cutting force is the force which has to act on the on the stock material in order to cut out the blank or slug. This determines the capacity of the press to be used for particular tool. The first step in establishing the cutting force is to determine the cut length area. The area to be cut is found by multiplying the length of cut by stock thickness. Resistance begins when the punch contacts the stock material. The load builds up rapidly during the plastic deformation stage and continues to increase while penetration is taking place. The accumulated load is suddenly released when fracture occurs. If proper cutting clearance condition exists between the punch and the die the fracture will occur when the cutting force equals the shear strength of the material.

Wear rate calculation:

Wear analysis on tool during piercing process in this study, Orchard's wear model which is applied widely to wear behavior is used In order to predict wear profiles on tool.

Uncoated: h = 697 Hv

w = kpl/3h

= 1x10-9 x 656 x 7.5 / 3 x 697

= 2.353×10^{-9} mm

TiN coated

h = 2300 Hv

w = 1x10-9 x 656 x 7.5 / 3 x 2300

w = 7.13×10^{-10} mm

TiAlN coated

h = 3300 Hv

w = 1x10-9 x 656 x 7.5 / 3 x 3300

w = 4.97×10^{-10} mm

The calculation shows the TiAlN is 4.734 times better wear resistant than uncoated M2 steel punch-un coated Punch life: 2401 No's / punch. Projected punch life for TiN coated punch: 2401 x 3.29 = 7923 No's / punches projected punch life for TiAlN coated punch: 2401 x 4.734 = 11367 No's / punches

Theoretical Cost per piece:

Operation Cost per Piece			
S.No.	**Description**	**Total cost**	**cost/hour(Rs)**
1	Machine cost	Rs.508086	**5.88**
2	Energy cost	(15u/hrs)	**75**
3	Manpower Cost	(rs18000/30days)	**37.5**
4	Punch cost	(2401 nos/punch)	**432.32**
5	Tool cost	Rs.58411	**46.72**
6	Other Cosn.cost		**2.55**
	Total cost / hour		**599.97**
	Production per hour	400	
	Cost / Piece	Rs	**1.50**

Table 1.2 Theoretical costs for uncoated punch

Operation Cost per Piece			
S.No.	Description	Total cost	cost/hour(Rs)
1	Machine cost	Rs.508086	5.88
2	Energy cost	(15u/hrs)	75
3	Manpower Cost	(rs18000/30days)	37.5
4	Punch cost	(7923 nos/punch)	189.92
5	Tool cost	Rs.58411	46.72
6	Other Cosn.cost		2.55
	Total cost / hour		357.57
	Production per hour	400	
	Cost / Piece	Rs	0.894

Table 1.3 Theoretical costs for TiN coated punch

Operation Cost per Piece			
S.No.	Description	Total cost	cost/hour(Rs)
1	Machine cost	Rs.508086	5.88
2	Energy cost	(15u/hrs)	75
3	Manpower Cost	(rs18000/30days)	37.5
4	Punch cost	(11367 nos/punch)	132.38
5	Tool cost	Rs.58411	46.72
6	Other Cosn.cost		2.55
	Total cost / hour		300.03
	Production per hour	400	
	Cost / Piece	Rs	0.750

Table 1.4 Theoretical costs for TiAlN coated punch

Metallurgical Test Report for Punch						
Material Grade :M2	**Part Name: Piercing Punch**		**punch Size: 26 ϕ**			
1. Grain Size	ASTM 6 - 7		ASTM Grain Size No 6-7		√	
2. Microstructure	Tempered martensite and clusters of carbides with presence of some retained austenite.		Tempered martensite and clusters of carbides with presence of some retained austenite.		√	
3. Surface Hardness	59-62 HRC	654-688 BHN	62 HRC	688 BHN	√	
4. Core hardness	59-62 HRC	654-688 BHN	62 HRC	688BHN	√	

Table: 1.5 Metallurgical Test Report

Micro structural Characterization	
Microphotographs at 100 X (Polished & Etched with Nital)	
Location : Surface	Location: Core
	
Remarks: Tempered martensite and clusters of	Remarks: Tempered martensite and clusters of

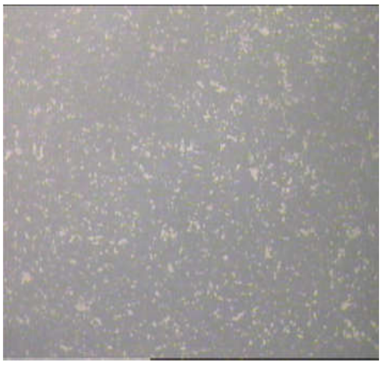
<table>
<tr><td>carbides with presence of some retained austenite.</td><td>carbides with presence of some retained austenite.</td></tr>
<tr><td colspan="2">Location: Core 400x</td></tr>
<tr><td colspan="2">
Remarks: Tempered martensite and clusters of carbides with presence of some retained austenite.</td></tr>
</table>

Figure: 1.1 Micro Structures

Crack Detection

Punch is inspected for any cracks on the surface & subsurface, Carrier II is a wet (oil) method magnetic particle oil carrier. The florescent power is mixed with carrier oil and applied on the part, when the current is passed the part get magnetized. florescent power fills the area if any crack on the part. The inspection is done on the ultra violet light. If there is any crack it will be shown as a line.

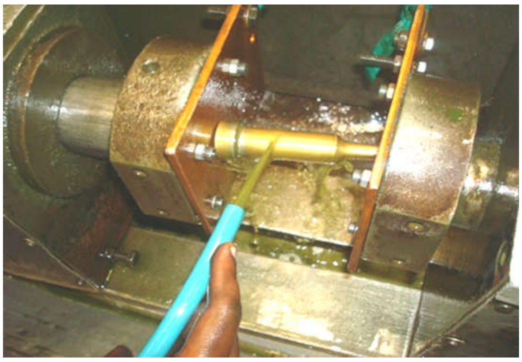
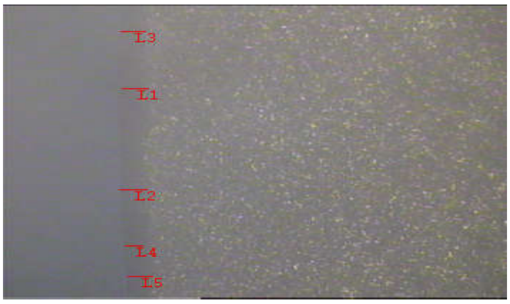


Figure: 2.1 crack detection M/CFigure: 2.2 Magnetizing, applying the oil and florescent powder

Figure:2.3 Inspection under U/V light Figure: 2.4 Demagnetization of punch



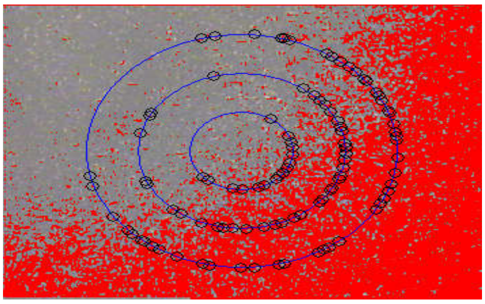


Figure: 2.5 Microscopic view of TiAlN coating Figure: 3.6 Grain size of TiAlN coating

Punch Performances: punch tool life are monitored with the production quantity.
Uncoated Punch Performance:

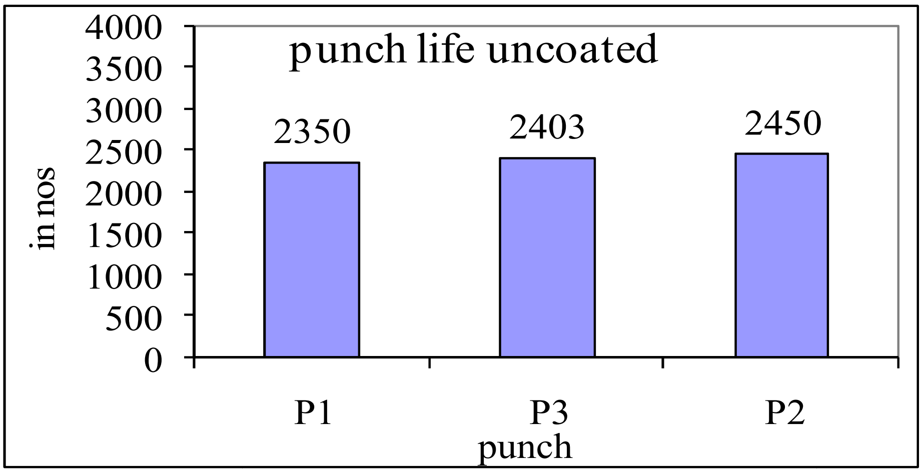


Figure 3.1: Un coated punch life

In this graph shown the performance of no of work piece vs. uncoated punch tool (Fig 3.1), Here P1, P2, P3 punch tool life were Monitoring from production quantity.

Tin coated Punch Performance:

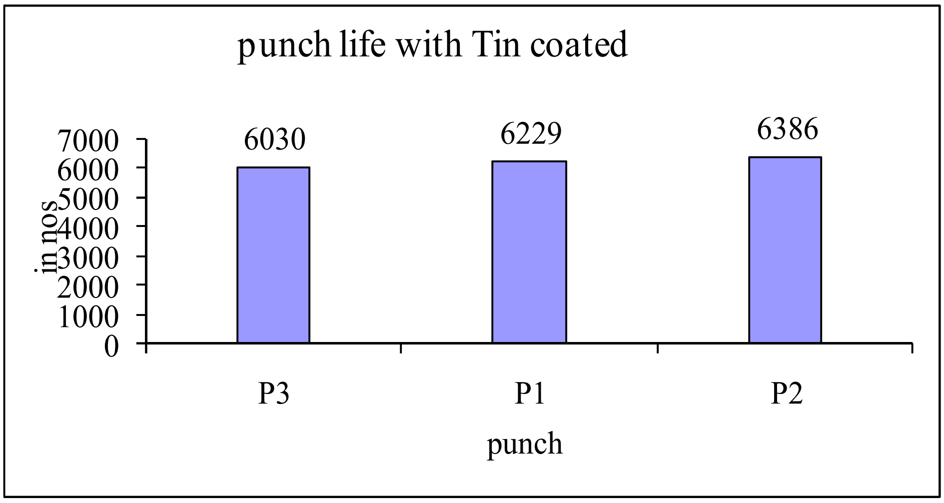


Figure 3.2: TiN coated punch life

In this graph shown the performance of no of work piece vs. Tin coated punch tool (Fig 3.2). Here P1, P2, P3 punch tool life were Monitoring from production quantity.

TiAlN Coated Punch Performance:

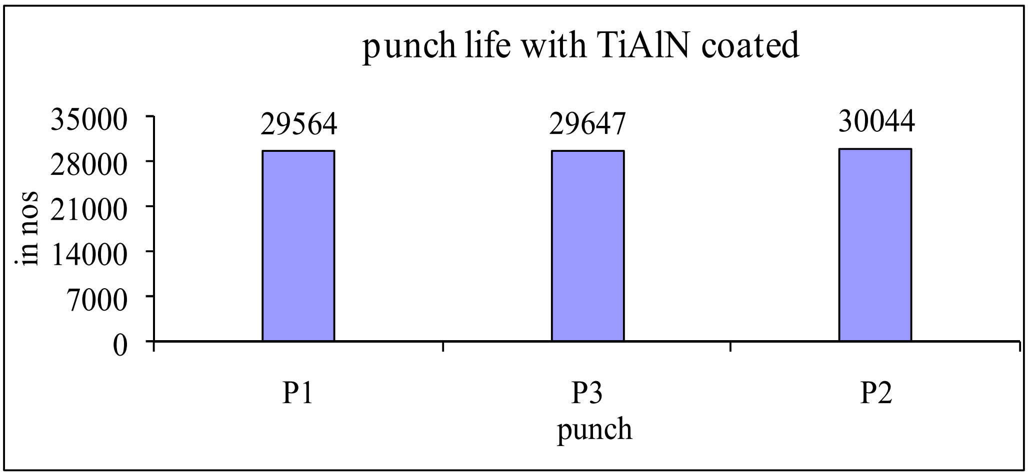


Figure 3.3: TiAlN coated punch life

In this graph shown the performance of no of work piece vs. TiAlN coated punch tool (Fig 3.3), Here P1, P2, P3 punch tool life were Monitoring from production quantity.

Comparison of Punch Life

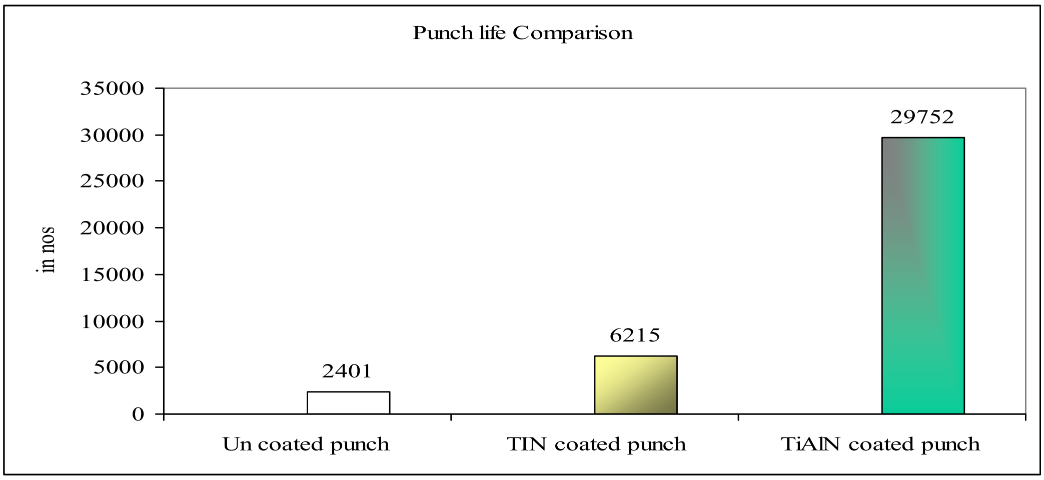


Figure 4: punch life comparison

In this graph shown (Fig 4), the performance of no of work piece vs. punch [Coated and uncoated] tool.TiAlN punch tool life was increased due to mechanical properties changes.

ACTUAL COSTS:

Operation Cost per Piece (with out coating)			
S.No	Description	Total cost	cost/hour(Rs)
1	Machine cost	Rs.508086	5.88
2	Energy cost	(15u/hrs)	75
3	Manpower Cost	(rs18000/30days)	37.5
4	Punch cost	(2401 nos/punch)	432.32
5	Tool cost	Rs.58411	46.72
6	Other Cosn.cost		2.55
	Total cost / hour		599.97
	Production per hour	400	
	Cost / Piece	RS	1.500

Table: 2 Actual Operational cost of uncoated punch

Operation Cost per Piece (TiN coated)			
S.No	Description	Total cost	cost/hour(Rs)
1	Machine cost	Rs.508086	5.88
2	Energy cost	(15u/hrs)	75
3	Manpower Cost	(rs18000/30days)	37.5
4	Punch cost	(6215 nos/punch)	267.54
5	Tool cost	Rs.58411	46.72
6	Other Cosn.cost		2.55
	Total cost / hour		435.19
	Production per hour	442	
	Cost / Piece	RS	0.985

Table: 3 Actual Operational cost of TiN coated punch

Operation Cost per Piece (TiAlN coated)			
S.No	Description	Total cost	cost/hour(Rs)
1	Machine cost	Rs.508086	5.88
2	Energy cost	(15u/hrs)	75
3	Manpower Cost	(rs18000/30days)	37.5
4	Punch cost	(29752 nos/punch)	70.43
5	Tool cost	Rs.58411	46.72
6	Other Cosn.cost		2.55
	Total cost / hour		238.08
	Production per hour	557	
	Cost / Piece	RS	0.427

Table: 4 Actual Operational cost of TiAlN coated punch

Comparison:

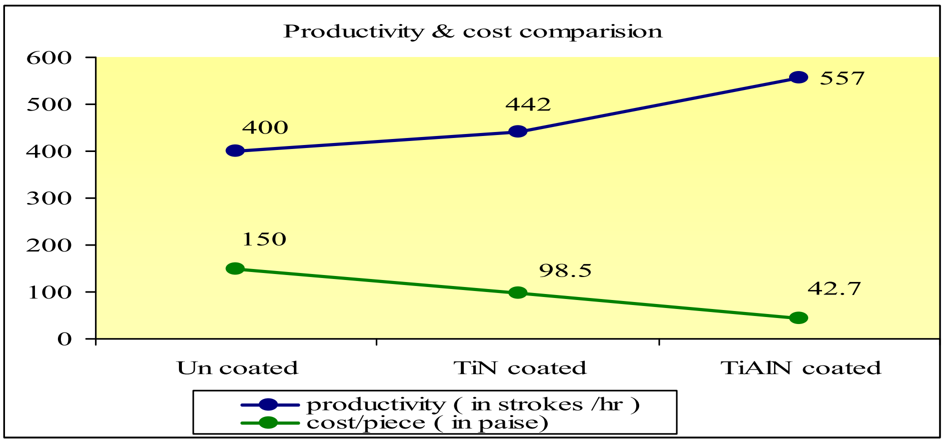


Figure 5.1: productivity and cost comparison

In this graph shown, productivity and cost comparison [fig 5.1]. It was shown, the better result in TiAlN coated only due to mechanical properties.

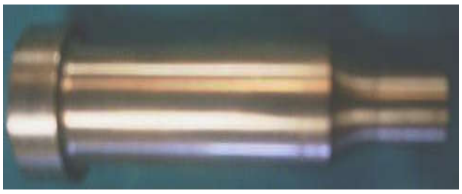
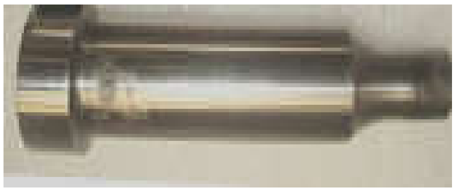
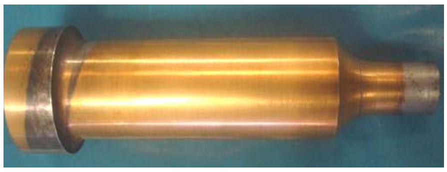
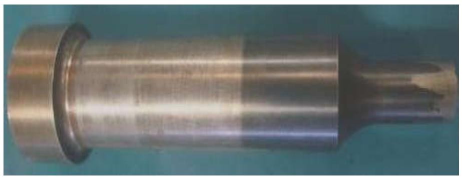
S.No	Before	After
Uncoated punch		
TiN coated punch		
TiAlN coated punch		

Figure 5.2: Photos of punch before and after trial

The figure 5.2 had shown the performance with uncoated punch and TiAlN coated punch. It was shown, the better result in TiAlN coated only due to mechanical properties.

CONCLUSION

1. Piercing punch life tests were conducted using uncoated M2 punch and punch coated with TiN, TiAlN.
2. Results shows that the TiAlN coating was the highest wear resistance, followed by the TiN coating.
3. From this figure: 19 it is obvious that TiAlN is the best, and TiN is the second best coating for piercing of steel.
4. The TiAlN coating yielded an average of 12.39 times tool life over the uncoated punch TiN did fairly well, with an average factor of 2.58.
5. In this project we reconfirmed the PVD coating with TiAlN nano structured coating was better wear resistant for cold piercing operations

REFERENCES

1. YuehJawLin , Ashutosh Agrawal, Yunmei Fang,(2008).“Wear progressions and tool life enhancement with AlCrN” Wear 264 ,PP 226–234”
2. M.H.Staia, Y.perez-Delgado, C.Sanchez, A.Castro (2009).“hardness properties and high temperature wear behavior of Nitrided AISI D2 steel, prior and after PVD coating” Wear 267, PP 1452-1461”
3. M. Sokovi, B.Bariˇsi S.Sladi´cb (2009).Model of quality management of hard coatings on ceramic cutting tools”209,Year-(2009), PP 4207-4216 ”
4. Jie Gu, Gary Barbe, Simon Tung, Ren-Jyh Gu (1999).“ Tool life and wear mechanism of uncoated and coated milling inserts” Wear 225-229 , PP 227–28
6. E. Marin , R. Offoiach , M. Regis , S. Fusi , A. Lanzutti , L. Fedrizzi (2016).“Diffusive thermal treatments combined with PVD coatings for tribological protection of titanium alloys” Materials and Design 89 , PP 314–322

7. Xingguang Liu, John Kavanagh, Allan Matthews, Adrian Leyland, (2015).“The combined effects of Cu and Ag on the nanostructure and mechanical properties of CrCuAgN PVD coatings” Surface & Coatings Technology 284 ,101–111
8. Krishna Valleti , D.MuraliKrishna, P.MohanReddy, ShrikantV.Joshi,(2016). “High temperature stable solar selective coatings by cathodic arc PVD for heat collecting elements” Solar Energy Materials & SolarCells 145, PP 447–453
9. M. Sivapragash P. Kumaradhas B. Stanly Jones Retnamb, X. Felix Joseph , U.T.S. Pillai, (2016).“Taguchi based genetic approach for optimizing the PVD process parameter for coating ZrN on AZ91D magnesium alloy” Materials and Design 90, PP 713–722
10. B. Koyilada, S. Gangopadhyay, A. Thakur, (2016). “Comparative evaluation of machinability characteristics of Nimonic C-263 using CVD and PVD coated tools” S0263-2241, PP 00100-7
11. Mário Vančo, Jan Krmela, Františka Pešlová, (2016).“The use of PVD coating on natural textile fibers “Procedia Engineering 136, PP 341 – 345
12. Martina Grandin ,Urban Wiklund, (2016).“Wear and electrical performance of a slip-ring system with silver-graphite in continuous sliding against PVD coated wires” wear, PP 138–147.