International Engineering Research Journal Page No 1849-1854

Study and Analysis of PVD Coating on Piercing Punches to Improve Its Life

Gaurav M. Bhavar[1],Department of mechanical Engineering,*G.E.S's.R.H.S.C.O.E.&M.R.,Nasik*-05,India gauravbhavar3@gmail.com[1]
Prof. K.V.Chandratre[2],Department of mechanical Engineering,*G.E.S's.R.H.S.C.O.E.& M.R.,Nasik*-05,India ckailas@rediffmail.com[2]

***Abstract*—The main aim of paper is to predict influence of PVD coatings are applied on Piercing punches. In this study Piercing punches are coated with three different coatings of TiN, TiCN and CrN. Coatings plays important role to achieve the performance of piercing operation economically and to boost productivity. Mostly coatings are provided to overcome the tool wear, to increase hardness of tool and to reduce corrosion and oxidation, etc. Tool failure generally occurs due the more plastic deformation or fracture of tool.**

The main aim of this research is to improve the piercing punch life. This study explores the actual industrial case study. Experimentations on piercing punch are carried with TiN, TiCN and CrN coatings by PVD technique. The results are validated with the help of FEA software.

***Index terms*— Coating, Piercing punch, wear, PVD**

I. Introduction

FOR conventional machining tool wear problem is unavoidable, PVD Coatings are the solution for this problem. i.e. cutting tools, plastic injection molding die, and tools for powder compaction etc. PVD coated tools, increases productivity viz. longer tool life, higher cycle frequencies, and less workpiece finishing, etc. also reduces manufacturing cost due to smoother surfaces, higher degree of metal deformation.

In cutting tools, it is necessary that tool must have hardness, high strength, abrasion resistant, as well as it must be chemically inert to prevent the chemical reaction between the newly generated surface of work piece and that of tool. Effectiveness of tool depends on fine grained free of binders and porosity. Naturally coating must be metallurgic to the substrate.

All these advantages can be reaching in metal cutting, sheet metal work, cold forming, pressure die casting and plastic processing. The application of PVD coating to improve tribological properties of tools (e.g. for metal forming and metal cutting) and machine element are constantly increasing.

Coated tools are finding wide acceptance in many manufacturing applications. Coated tools have two or three times the wear resistance than the best uncoated tools. Therefore, these tools have a broader range of applications. The advancement of coated tool technology has greatly attributed the advancement in manufacturing technology. There are basically two types of coating method named as chemical vapour deposition (CVD) and physical vapour deposition (PVD).

II. Literature review

Aleksei tshinjana et al., (2012) describes in his paper that tool life can be prolonged by application of high performance alloy steels or ceramic-metal composites. Application of ceramic metal composites is limited by size of parts and the cost. For these tools from high alloy steel, particularly these with coatings, are used. Thin but hard single or multilayer coatings like TiN, TiCN, (Al, Ti) N are widely used to protect against wear and corrosion .use of thin coatings enables adhesion, abrasion and diffusion wear and friction to be reduced and heat resistance to be enhanced. Coatings processes like chemical vapour deposition and physical vapour deposition are increases tool life. The reason of PVD has become increasingly favorable over CVD when coating high alloy steel is the fact coating process occurs much lower deposition temperature (400°C -600°C).Other advantage of PVD Coating is ability to deposited much thinner films. A PVD technique is introduced in various machining and abrasion application. Thus study of this paper performance of tool steels, strengthened by PVD coatings, working in adhesion wear condition (metal cutting, forming and particularly in blanking).

R. Hambali et al., (2003) worked on tool wear and changed geometry of punch and die, clearance. The process of shearing and form of sheared surface was influenced by tool wear. He advised effect of dimensional accuracy and surface finish of product. It described phenomena related to wear and its impact on economy of industrial metal blanking processes. A quantitative approach to tool wear analysis would improve service life, leading to an important reduction in manufacturing costs.

Paper mentioned to provide a general finite element model allowing for numerical simulation of the punching process. The numerical results to verify the validity of proposed finite element model in describing the impact of tool wear.

Shanyong Zhang (1993) has described about metal processing technology and TiN Coated tool steel. Titanium Nitride is widely used in application of tool industries. The advantages of TiN coatings tool steel as noble appearance, excellent adhesion to substrate, chemical inert, and resistance to elevated temperature, a low coefficient of friction with workpiece materials which increases lubricity and results in excellent surface finish.to keep all condition equivalent, tool life improvement can be evaluated by comparing the increases no. of workpiece machined by TiN tool.

The reason of coating on cutting tools in a production situation is increases tool life, to improve surface quality of the product and production rate increases. It was concluded that TiN Coating of tool steel was proven way of success in boosting production and curtailing cost. However PVD process more appropriate than CVD processes.

Melcot Jinikol (2009) Describes the important factor which controls the quantity of the product was tool life. For improving of the quantity of the product, one needs to maximize the tool life. There are lots of factors or parameter that will affect the life of tool. Main factor in the punching tool is wear that decreases the tool life. Tools often show adhesive and abrasive wear in the contact zone.

In this study the parameter that can affect the wear like the shear angle of cutting tool, punching force, and also what are type of wear that occur in the punching tool. Resulting may design the new tool geometry that less wear occur, that will increase tool life.

Soumya Subramonian (2013) the journal about manufacturing process Blanking is a commonly used in the production of a variety of parts ranging from (a) Small electronic and electrical components like pins and connector parts to (b) high strength components and stainless steels. Depending on the application Sheets of 0.2–20 mm thickness and higher are blanked or punched. To improve the productivity of the process Irrespective of the type and thickness of the sheet material used, longer punch and die life is desired. Improving the punch and die life is especially useful in the blanking precision parts in large quantities. For high volume production, to increase die life in reduces (a) the changeover/ tool sharpening time, and (b) alignment time for punch and die and other tooling components. The various parameter of punch and die life and edge quality in blanking depend on (i)punch-die clearance (ii) punch and die corner radius portion (iii) punch and die materials and coating (iv) blank sheet material (v) stripper force and (vi) lubrication In this study, the conclusion of punch-die clearance is investigated further punch and die life to improve.

N. Balasubramanyam et al., (2015) worked on very common industrial challenge in cutting tool industries was constantly facing of reducing cost of machined parts and at the same time improving the quality of the machined surface. Improving cutting tool materials these issues were generally addressed, to improving the geometry and surface characteristics of the cutting tools, optimizing machining parameters applying advanced coating. The contributes in reducing cost per machined parts through increasing productivity need for the use of newer cutting tool materials to combat hardness, wear situation has resulted in the occurrence surface coatings, and encompassing tool life. higher hardness, low friction at the chip tool contact, higher wear resistance, high hot hardness and high thermal and chemical stability these benefits of advanced coatings .To avoiding any built-up edge due to the reduced friction between the tool and work piece the machined surface quality with the coated cutter can also be developed. It is necessary to develop TiN, TIC, coatings on Tungsten carbide cutting tool Because of the abundant advantages of surface coatings and the requirement of industrial growth and condition, it was essential to do surface coating of TiN, TIC, on Tungsten Carbide cutting tool to give good mechanical and tribological properties which is Based on driving force.

Y.B. Kumbhar et al., (2013) in this paper, tell about optimum process parameters for turning while semi hard machining of hardened EN31 alloy steel by using Taguchi approach. analysis of variance (ANOVA) were applied to study performance characteristics of machining parameters mostly included cutting speed, feed rate and depth of cut with consideration of surface finish and tool life. The conclusions publicized that the feed rate was the most leading factor on the surface roughness and tool life.

In physical vapor deposition (PVD) technique on tungsten carbide material advanced multilayer thin coatings deposited which used in order to increase wear resistance and decrease insert chipping.

The relative responses of Tool wear, cutting force, surface roughness and cutting power. Tool wear results in changes in tool geometry that affect cutting forces, cutting power, and surface finish. It is the main factor that defines the economics in metal cutting. A lower wear rate of tool means increased tool life, better surface finish, reduced tooling cost and lower cost of production.

In case of PVD TiAlN coating, at higher temperature the improvement in the cutting performance was due to the oxidation resistance of TiAlN properties. For the outstanding property of TiAlN High wear resistance even at high temperatures, a characteristic that makes this coating valid to cut abrasive work piece material such as aluminium silicon alloys, cast iron, and composite materials at high speeds.

III. MANUFACTURING TECHNIQUES OF COATINGS

A. Pvd coating-

Physical vapour deposition (PVD) by the condensation of a vaporized form describes a variety of vacuum deposition methods used to deposit thin films of the desired film material onto various work piece surfaces. The coating method includes decently physical processes such as high-temperature, vacuum evaporation, with subsequent condensation, or plasma sputter bombardment, relatively than involving a chemical reaction at the surface to be Coated as in chemical vapour deposition. Physical vapour deposition (PVD) is a group of thin film in which material is converted into its vapour phase in a vacuum chamber and a substrate surface onto condensed as a very thin layer. Different PVD technologies utilize the same three fundamental steps but differ in the methods used to generate and deposit material.

These PVD coating processes the most common of are evaporation (normally using cathodic arc or electron beam sources), and sputtering (using magnetic enhanced sources or “magnetrons”, cylindrical or hollow cathode sources). All of these processes working in vacuum at pressure (typically 10^{-2} to 10^{-4} mbar) and coating process to promote high density generally include bombardment of the substrate to be coated with energetic positively charged ions. To create various compound coating compositions introducing reactive gases such as nitrogen, acetylene or oxygen into the vacuum chamber during metal deposition. This gives strong bond between the coating and the tooling substrate and made-to-order physical, structural and tribological properties of the film.[3]

B. Significance of coating study-

Coatings significantly improve tool life and enhancement the performance of tools in high-productivity, high speed and high-feed cutting or in machining, and when machining of difficult to- machine materials.

Coatings:

(a) Provide increased surface hardness, for greater wear,

(b) Increase resistance to (abrasive and adhesive wear, flank or crater wear),

(c) Reduce friction coefficients to ease chip sliding, reduce cutting forces,

Prevent adhesion to the contact surfaces; reduce heat generated due to chip sliding etc. So, ultimately it effects on the press tool overall productivity, additionally, it helps to improve the quality of the parts produced. Hence, the coating effect on the tools is more important.

C. coating characteristics-

Common coatings applied in single- or multi-layers they are:-

Titanium nitride (TiN) - Which is gold-coloured coating offers excellent wear resistance with a wide range of materials, and allows for higher feeds and speeds. Forming operations and Piercing can expect a decrease in galling and welding of workpiece material with a corresponding progress in the surface finish of the formed part.

Titanium carbonitride, (TiCN)- is Bronze-coloured Ti(C,N) which offers improved wear resistance with abrasive, adhesive or difficult-to-machine materials such as cast iron, alloys, tool steels, copper and its alloys, Inconel and titanium alloys. As with TiN, feeds and speeds can be increased and tool life can improve.

Chromium nitride, (CrN) - Silver in colour, CrN offers high thermal stability, which in turn helps in the aluminium die casting and deep-draw, Piercing applications. It can also reduce build-up edge commonly associated with machining titanium alloys with Ti-based coatings.[12]

IV. ORIGIN OF RESEARCH PROBLEM

In press tool, specifically piercing punch faces problem of wearing. Type of wear includes viz. flank wear, crater wear; also contact of the punch, elastic and plastic deformation, fracture shearing and crack formation, etc. In piercing punch part edge characteristics, punch / die wear, punch-die clearance, punch corner radius are also varied eventually; because of which tool life is reduced, accuracy of punch and die decreased and it reflects in the cost as well as quality of parts.

V. METHODOLOGY OF COATING

A. Experimental analysis-

In this methodology the practical results on actual working on press machine. Piercing operation observes regular punches wear out in that edge chip off, worn out, or even broken punches. It also comparing with coating punches in which TiN, TiCN and CrN Coating and validates the results of the same.[9, 15]

The standard punches are made up of HCHCr steel materials. In this HCHCr tool observes more tool wear. To enhance these wear problem three different types of coating are applied on tool viz. TiN, TiCN and CrN, etc.

The following two figures indicate the tool wear in HCHCr material. So it proposed that applying coating of TiN, TiCN and CrN these layers and observed the results.

Fig. 1.Worn out punches

TABLE I
NON COATED

Sr.No	Month	Total Strokes	Punch Worn Out	Percentages
1	Apr-16	4000	2350	58.750
2	Mar-16	3500	1500	42.857
3	Feb-16	4000	2300	57.500
4	Jan-16	3000	1855	61.833
5	Dec-15	3500	1650	47.143
6	Nov-15	4000	2260	56.500

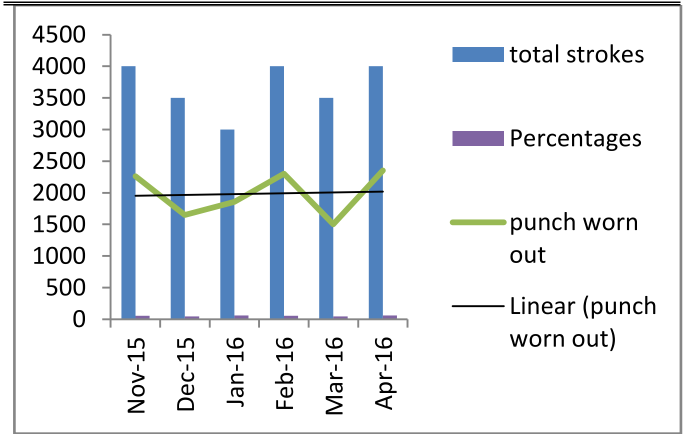


Fig. 2.Graph of worn out punches

VI. RESULT AND DISCUSSION

A. Industrial Trials-

In Sheet metals industry trials taken from past 6 month and data is monitored. It is observed that Piercing punches worn out almost 45% on monthly strokes basis as seen in table I.

Whereas same materials with same diameter of punches made with 3 different types of coatings such as TiN,TiCN and CrN. From table II, It is clear that punches worn out are very low as only 10 to 15 % compared to non-coated punches. It is directly indicates that life of coated punches are more than that of non-coated.

B. Analysis by FEM Software-

Using FEM software total deformation, equivalent stress and shear stress non-coated and coated of punches are noted. It can be seen in table III and IV respectively. Total deformation is more in coated punches than non-coated also in coated punches case 2 observed that shear stress is less ,so less wearing of punches.

TABLE II
WITH COATINGS

Sr.No	Month	Total Strokes	Punch Worn Out		
			Case1 TiCN	Case2 TiN	Case 3 CrN
1	Apr-16	4000	3600	3400	2800
2	Mar-16	3500	3200	2900	2800

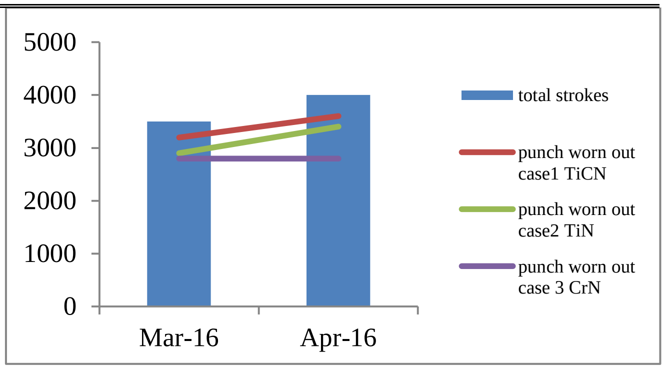


Fig. 3.Graph of coated punches

From above table it is observed that coated punches are given good working life as compared to non-coated punches. In coated TiCN is best way of coating in piercing tool than TiN and CrN.

B. Design Analysis-

Model is drawn from Catia-V5 Software for analysis purpose. Three Piercing punches of different diameter have same materials. As shown as follows-

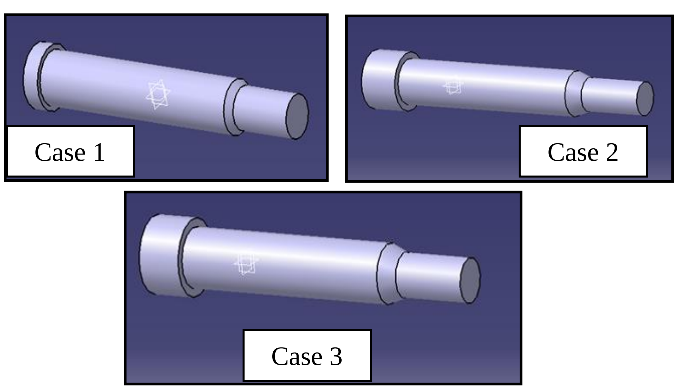


Fig. 4.Model of three cases Piercing punches

The standard Piercing Punch of material HCHCr steel (ASTM-A-781).

Case 1 indicates cutting diameter of punch 12.80mm
Case 2 indicates cutting diameter of punch 10.50mm
Case 3 indicates cutting diameter of punch 8.80mm

With the help of ANSYS software many results were effectively findout. [1, 5]

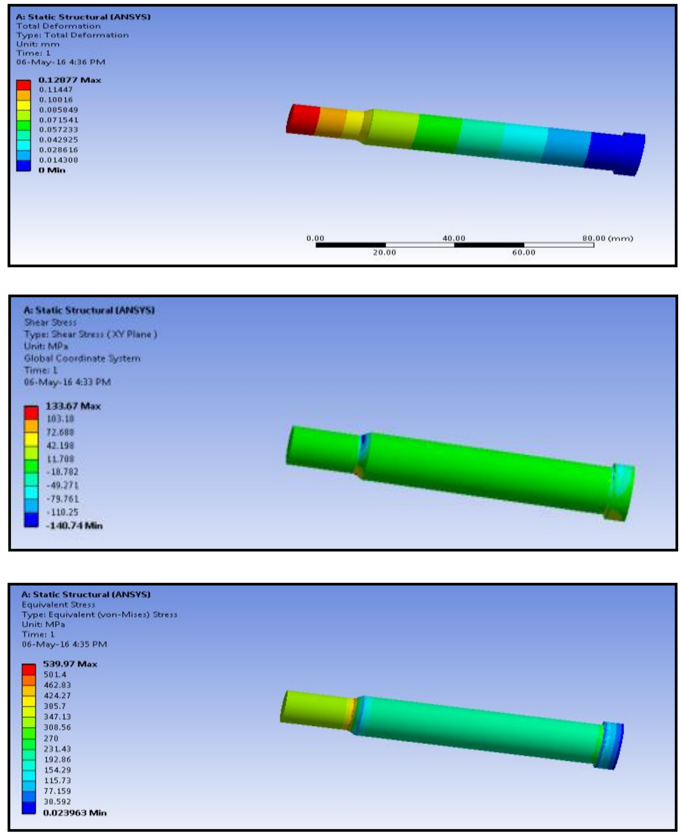


Fig. 5.Analysis of punches non-coated in FEM software

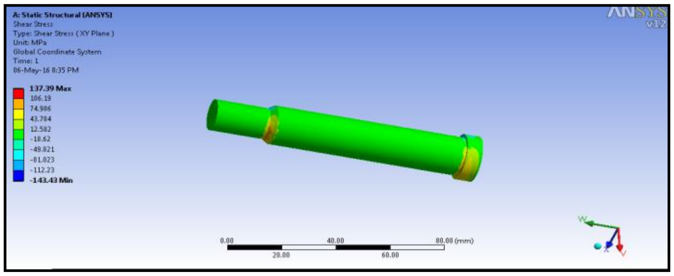
TABLE III
RESULT OF FEM SOFTWARE NON-COATED PUNCHES

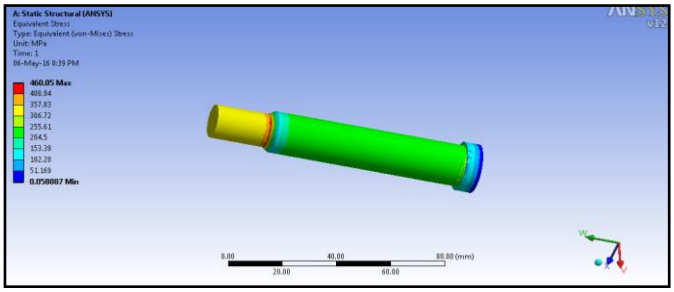
Results non coated (HCHCr as Material)	Case1 D=12.80mm	Case2 D= 10.5mm	Case3 D=8.8mm
Total deformation (mm)	0.128	0.123	0.111
Equivalent stress (MPa)	539.97	553.96	624.87
Shear stress (MPa)	133.67	138.07	133.95

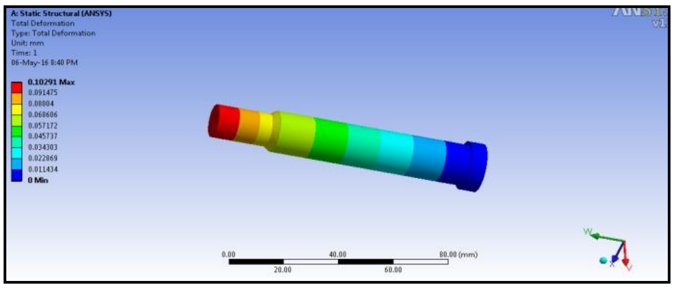
From the above table it observed that in case 3 less deformation and High Equivalent stress were observed. Further results were observed by applying coatings of-

CASE 1- TiN, CASE 2 –TiCN, CASE 3 – CrN

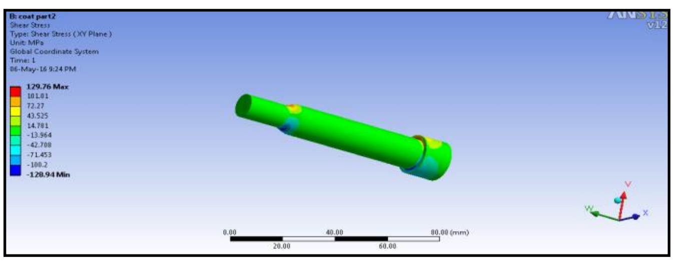
CASE 1 –TiN:

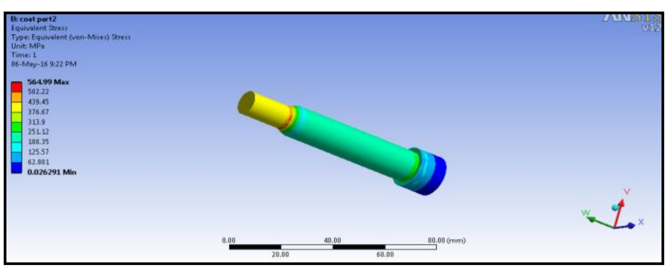


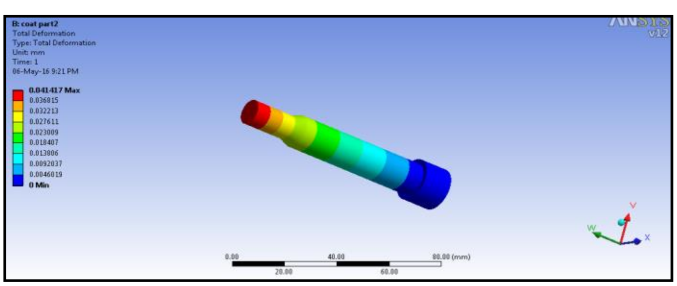




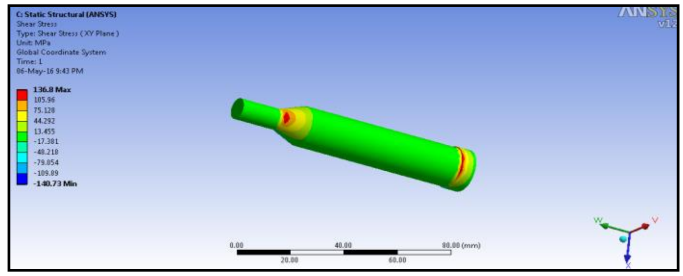
CASE 2 –TiCN

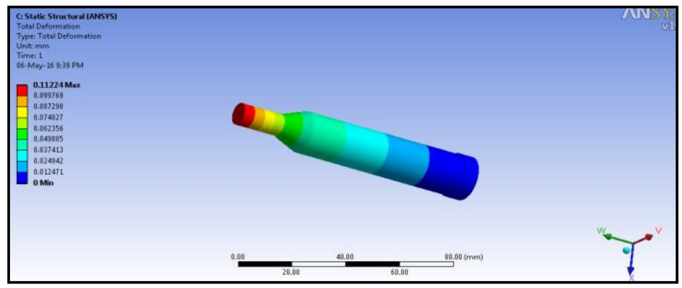


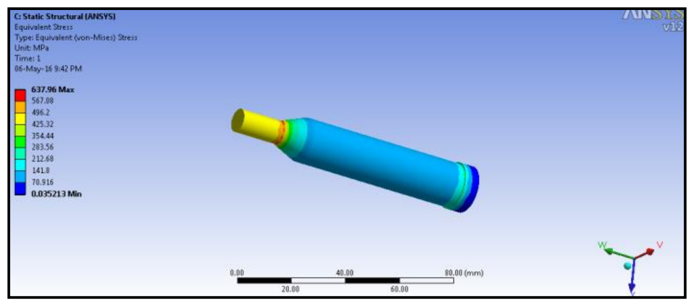




CASE 3 – CrN







The above software output results are tabulated below

TABLE IV
RESULT OF FEM SOFTWARE WITH COATED PUNCHES

Results with coated	Case1 (TiN) Dia of 12.80mm	Case2(TiCN) Dia of 10.5mm	Case3(CrN) Dia of 8.8mm
Total deformation (mm)	0.102	0.414	0.112
Equivalent stress (MPa)	460.5	564.9	637.96
Shear stress (MPa)	137.39	129.76	136.8

The above table shows that total deformation is more in TiCN and having in between Equivalent Stress as compared to others.

VII. ADVANTAGES OF PVD

In this Study of PVD Coating, following are advantages -

a. Increases the surface hardness for a crater wear.
b. Increases resistances to (abrasive, adhesive wear, flank or crater wear).
c. Reduced friction coefficient to ease chip sliding reduced cutting force, reduced heat generated due to chip sliding.
d. Increases corrosion and oxidation resistances.
e. Improve surface quality of finished parts.

VIII CONCLUSION

PVD coatings are mostly used for simple type of tools and operations. This process operates at temperature 320°F to 800°F which is lower than other methods. It also takes up convenient time for process as depends on tool size. Also wide ranges of materials substrates can be used. It gives very good surface finish. The high hardness, wear resistance and chemical stability of these coatings offer proven benefits in terms of tool life and machining performance.

In this study the piercing punches are coated with PVD technique using TiN, TiCN, and CrN. After trials of the punches, the tool life is increased substantially by 80 %. The study shows that TiCN coatings are giving good results for piercing punch. The results are validated with FEA analysis.

REFERENCES

References Papers:

[1] R. Hambli et. Al., Numerical Evaluation of the Tool Wear Influence on Metal-Punching Processes (2003) 21:483–493.
[2] Soumya Subramonian et al., Optimum selection of variable punch-die clearance to improve Tool life 75(2013)63–71.
[3] Aleksei Tshinjana et al., Wear performance of PVD coated tool steels, 2012, 18, 3, 202–210.
[4] Shanyong Zhang, TiN coating of tool steels: a review , Journal of Materials Processing Technology, 39 (1993) 165-177.
[5] Melcot Jinikol, Punching Tool Wear Modeling Using Finite Element Method , NOV 2009
[6] Y.B.Kumbhar et al., International Journal of Advanced Engineering Research and Studies. s / II/ IV/ , July-Sept., 2013/22-27
[7] N. Balasubramanyam et al., International Journal of Advanced Science and Technology Vol.75 (2015), pp.51-58, 2015

References books:

[8] K. Bobzin et al., Surface & Coatings Technology 203 (2009) 3184–3188
[9] B. Podgornika et al.,Wear 270 (2011) 850–856
[10] D. Mari and D. R. Gonseth, A New Look at Carbide Tool Life, Wear, 165 (1993) 9-17.
[11] Fritz Klocke, Manufacturing Processes 1, Springer ISBN 978-3-642-11978-1.
[12] Viktor P. Astakhov and J. Paulo Davim Tools and Tool Wear, Springer 1996.
[13] S. Hogmark et al., Surface and Coatings Technology, 90 (1997), 247-257
[14] W.Grzesik, Advanced Protective Coatings for Manufacturing and Engineering, Cincinnati 2003, 40-55
[15] S. Hogmark et al., Wear, 246 (2000), 20-33
[16] Schuler – Metal Forming Handbook, Springer, 1998.

Gaurav Madhukar Bhavar received Mechanical Engineering degree in College from K.K.WAGH College of Engineering, Nashik, University of Pune in 2013 year and applied for the Masters of Mechanical Design Engineering from G.E.S.'s. College of Engineering, Nashik, University of Pune in 2014-2016 year. Currently working as Executive Engineer in Tool Room since 2014 to till date in JBM Auto, Nashik.

Prof. Chandratre Kailas V. graduated from Pune University, in 1996. He has post graduated from Shivaji University in Mechanical Engineering He has published several research papers. He has 20 years of teaching experience. Currently working as HOD in G.E.S.'s. College of Engineering, Nashik.