Journal of Experimental Agriculture International

44(7): 1-10, 2022; Article no.JEAI.86000
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Wear Resistant Nanostructured Coating for Cultivator Shovels

N. R. N. V. Gowripathi Rao [a*≡], V. Dave [b] and G. S. Tiwari [c]

[a] *Karnavati School of Research, Karnavati University, Gujarat, 382422, India.*
[b] *Department of Electrical Engineering, MPUAT Udaipur, 313001, India.*
[c] *Department of Farm Machinery and Power Engineering, MPUAT Udaipur, 313001, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2022/v44i730831

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/86000

Original Research Article

Received 12 February 2022
Accepted 27 April 2022
Published 30 April 2022

ABSTRACT

In Indian economy agriculture plays a principal source of income. Primary and secondary operations such as ploughing are the basic actions and extensive usage of cultivators for secondary tillage operation causes wear of the shovels because they are subjected to high tillage forces. An ample amount of material is lost due to wear and abrasion. Therefore, control and prevention of wear of cultivator shovels are vitally important for agro applications because wear of critical components has an economic significance. In this work CrN coating is deposited over cultivator reversible shovels using the DC magnetron sputtering technique and the structure, morphological, hydrophobic and wear characteristics are determined. It is observed that the working life of the agricultural tool is increased up to a significant level by depositing the desired coating on the substrate.

Keywords: Wear; DC magnetron sputtering; tillage; secondary equipment.

1. INTRODUCTION

Agriculture is the backbone of the Indian economy, with agriculture providing primary income to almost half of the Indian population. In India, farm mechanisation is regarded as one of the most significant aspects of agricultural modernization. From 0.636 t/ha in 1965-1966 to

---

≡ *Research Assistant Professor,*
**Corresponding author: E-mail: gowripathiraofmpe@gmail.com;*

2.111 t/ha in 2013-2014, the country experienced extraordinary rise in food grain productivity. The usage of agricultural technology on farms is largely to blame for this expansion. In India, average farm power availability rose from 0.30 kW/ha in 1960-1961 to 2.02 kW/ha in 2013-2014 [1].

Ploughing is one of the most basic primary and secondary processes required for the cultivation of any crop. Farmers employ a variety of implements, such as mouldboard ploughs, disc ploughs, and cultivators, under a variety of field situations. Cultivator is a type of soil engagement tool that, because of its broad soil coverage area between two furrows, is employed as a secondary tillage implement. Because shovels are subjected to strong tillage forces when cultivators are used for secondary tillage, they wear out quickly [2-8]. According to an estimate of material loss in grain farming in Turkey, 9700 t of steel is lost owing to wear and abrasion and the energy equivalent of cultivating an area of 13422000 ha twice.

Surface modification techniques such as coating can help to reduce the wear and abrasion of agricultural tools which can increase the life shell of agricultural tools. It is highly desirable to deposit hard protective coatings to increase the cost effectiveness, life and performance of the shovel. These procedures offer strong process stability, are cost-effective, and have been adapted for industrial production, however they are not environmentally friendly, and the coatings they produce have poor characteristics. The deposition of ions and molecules of a material is vaporised and transported through a vacuum or low pressure gaseous environment before condensing on a substrate in the physical vapour deposition (PVD) process. PVD methods may deposit films with thicknesses ranging from a few angstroms to a few dozen nanometres [9-13]. Vacuum evaporation, magnetron sputtering, sputter deposition, arc evaporation, low voltage electron beam evaporation, cathode arc deposition, triode high voltage electron beam evaporation, and ion planting are some of the most extensively used PVD processes using sputtering and evaporation technologies. But nanostructured thin films have attracted considerable attention in several applications like optoelectronics, electronics [14-17].

Magnetron sputtering is a physical vapour deposition (PVD) coating technique that can overcome many disadvantages associated with other techniques, such as low density, poor adhesion, and poor properties. Sputtering is a very flexible and effective deposition process for depositing various metallic and compound thin films for surface engineering applications. It holds many advantages like pure deposition, reproducibility, uniform deposition rate and good quality of film.

Hard protective coatings deposited by sputtering shows excellent physical properties such as high hardness, strength, toughness, chemical stability, wear and corrosion resistance [18-19]. It has been widely used as a thin protective film [20]. The sputter deposition technique can deposit coatings at low substrate temperatures or control the structure and properties of the deposited coatings by adjusting the deposition parameters [21].

Physical vapour deposition of chromium nitride in comparison to other nitride coatings through magnetron sputtering technique was a good alternative to other conventional surface treatments for protection against wear. CrN has better hardness, toughness and good tribological properties. Hard coatings are characterised by a relatively low friction coefficient, good wear resistance and a high corrosion resistance. The aim of this research was to deposit nanostructured coating material to enhance the life shell of the cultivator shovels [22-24].

In this study, we have deposited CrN over agriculture tool named reversible shovel on using the DC magnetron sputtering technique and investigated structure, morphological, hydrophobic and wear characteristics at different substrate temperatures as (100,150,200 ^{0}C). The coatings were characterized by X-Ray diffraction (XRD), Scanning electron microscopy (SEM) nanoroughness and hydrophobicity were determined using atomic force microscopy and contact angle goniometer. Wear test were carried out in a custom designed circular soil bin.

2. EXPERIMENTAL DETAILS

2.1 CrN film Processing

The CrN films were deposited by DC-magnetron sputtering technique on shovel (mild steel) as substrate in a custom designed 35 inch diameter chamber (Milman thin film systems). A 4 inch diameter and 6 mm thick chromium target of 99.99% purity was used for the sputtering. The substrate was thoroughly cleaned by rinsing in acetone and methanol and dried under nitrogen gas. The chamber was initially evacuated by a turbo molecular pump backed by a rotary pump. During each deposition, the base pressure was kept less than 5×10^{-6} Torr and the distance between the substrate and the target was kept 110 mm**.** The CrN coating was fabricated at As-deposited and 200 ^{0}C substrate temperature. The sputtering was carried out in an argon (99.99% pure) atmosphere while nitrogen was used as a reactive gas. The flow rate of nitrogen and argon in the chamber was 20 and 20 sccm, respectively. The gas pressure was kept 10 m Torr for all depositions.

2.2. Characterization Details

The structure properties of -CrN films were characterized by X-ray diffractometer (XRD) with Cu Kα radiation. Scan rate used was 2^0 min^{-1} and the scan range was from 10 to 70^0. The surface topography and elemental analysis of the film was studied using Scanning electron microscope (SEM) (Carl Zeiss) was carried out by using energy dispersive X-ray analysis (EDS). The surface morphology of the CrN films was studied using atomic force microscope (NT-MDT, Ntegra) operated in semi contact (tapping) mode. To determine whether the films are hydrophilic or hydrophobic by nature, contact angle measurement system (Kruss DSA 100 Easy Drop) was used to find contact angle of water with the films. Wear analysis was carried out in custom designed soil bin. A circular soil bin had an outer diameter of 5520 mm, inner diameter of 3490 mm and a depth of 900 mm.

3. RESULTS AND DISCUSSION

3.1 Structural analysis

X-ray diffraction analysis was carried out to determine the orientations and structural transformation of CrN films deposited at three different temperatures. Fig.1a and Fig.1b shows the XRD of the nanostructured films of chromium nitride deposited at 100, 150 and 200 ^{0}C and JCPS 11-0065 details of the CrN. The XRD curve clearly reveals that CrN film deposited at different temperatures are polycrystalline in nature and dominant peak occurs at $2\Theta = 37.56^o$ which corresponds to (1,1,1) orientation of cubic phase of CrN (JCPDS 11-0065). At 200 ^{0}C temperature the deposited film exhibited an intense and sharper diffraction pattern. The average crystallite size of the thin film was calculated using the Debye–Scherrer formula [25].

$$t = \frac{0.9\,\lambda}{\beta cos\Theta} \text{..................} \quad (1)$$

Where t is the crystallite size, λ the wavelength of X-ray (1.54056A˚), β the line width at half maximum of the most dominant peak and Θ Bragg diffraction angle. The crystallite size for 100, 150 , 200 ^{0}C substrate temperature coating were 18.97, 20.44 and 25.47 nm, respectively. Crystal size was found to increase with the rise in substrate temperature. The enhancement in the crystal size of chromium nitride films can be associated with the change in the kinetic energy of the sputtered particles with the temperature.

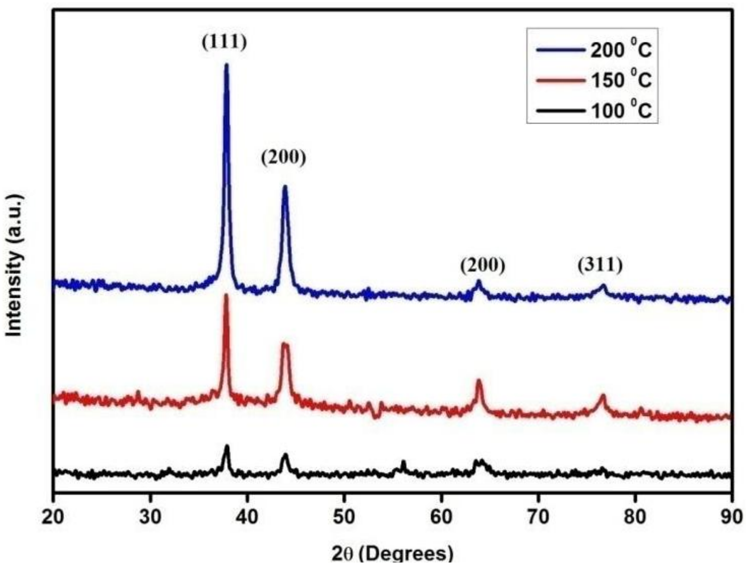

Fig. 1a. XRD patterns of CrN films deposited at different temperatures [26]

11-0065 Wavelength= 1.5418

CrN

Chromium Nitride

Carlsbergite, syn

Rad.: CuKa λ: 1.5418 Filter: Ni Beta d-sp: 9.0

Cut off: Int.: Estimation I/Icor.:

Ref: Turkdogan, Ignatowicz, J. Iron Steel Inst., London, 188, 242 (1958)

Sys.: Cubic S.G.: Fm3̄m (225)

a: 4.140 b: c: A: C:

α: β: γ: Z: 4 mp:

Ref: Ibid.

Dx: 6.178 Dm: 5.900 SS/FOM: F 9 = 11(0.092 , 9)

Color: Light gray, pink-violet in reflected light
Electron diffraction: a=4.139. Reference: Pinsker, Ambrosimova, Kristallografiya, 281, Sov. Phys. Crystallogr., 3 285 (1958). Cl Na type. Halite Group, nitride Subgroup. PSC: cF8. See ICSD 37412 (PDF 76-2494). Mwt: 66.00. Volume[CD]: 70.96.

2θ	Int	h	k	l
37.569	80	1	1	1
43.774	100	2	0	0
63.597	80	2	2	0
76.226	60	3	1	1
80.186	30	2	2	2
96.413	30	4	0	0
108.547	50	3	3	1
112.714	60	4	2	0
131.352	60	4	2	2
150.104	30			

PCPDFWIN v. 2.4

Fig. 1b.JCPS 11-0065 details of the CrN (Chromium Nitride)

3.2 Surface Morphology and Chemical Composition

The surface topography and chemical composition analysis was done through EDS and SEM as shown in Table 1. It shows the atomic (%) of chromium and nitrogen of deposited film at different substrate temperatures. It was clear from that the elements of Cr and N that they were dependent upon temperature. SEM images of film deposited at substrate temperatures are shown in Fig. 2. The Cr/N ratio was approximately 1 for film deposited at temperature 200^{o}C while that of As-deposited was less than one. The surface-nano roughness of the CrN films was studied using atomic force microscopy (AFM). The AFM micrographs correspond to a scan area of 2µm×2µm and two dimensional AFM images obtained for CrN films deposited at 100, 150, 200 ^{0}C are shown in Fig. 3. It was clear from the Fig. 3 that CrN films are constituted with a large number of nanograins. The surface roughness was calculated using the software attached with AFM and as shown in Table 1. It was clear that as substrate temperature was increased from 100 to 150 and 150 to 200 ^{0}C roughness value was also increased from 6.35, 8.48, 11.17 nm respectively. This behaviour of roughness was very well correlated to the particle size which was earlier calculated through XRD. The increment in substrate temperature increases the particle size which in turn enhances the roughness, while decrement in particle size reduces the roughness.

3.3. Hydrophobic Properties

The wettability of CrN coatings were evaluated by measuring the water contact angle goniometer at ambient room temperature. The distilled water droplet were dropped on the deposited coating surfaces using a micro syringe. Average value of the water contact angle was determined by experimental drop profiles at different positions for the same sample. The water contact angle as a function of sputtering temperature was measured and shown in Fig.4. A graph in Fig.4 shows relation between roughness, contact angle and substrate temperature. Water contact angle as measured of 100, 150 and 200 ^{0}C was 100, 102 and 105^{0} respectively which confirms that CrN coating was hydrophobic in nature.

3.4 Effect of Coating on Wear of Cultivator Shovels by Abrasive Sand

The effect of coating on gravimetric wear of reversible cultivator shovels was observed in a circular soil bin by using sand as abrasive medium. Test shovels S_1, S_2, S_3 with substrate temperature 100, 150 and 200^{0}C, respectively had almost equal hardness of 371 BHN and that were mounted on the tool frame for continuous testing in the soil bin. The moisture content of sand was kept 9-10%. Operating speed and depth of operation were 1m/s and, 100 mm, respectively.

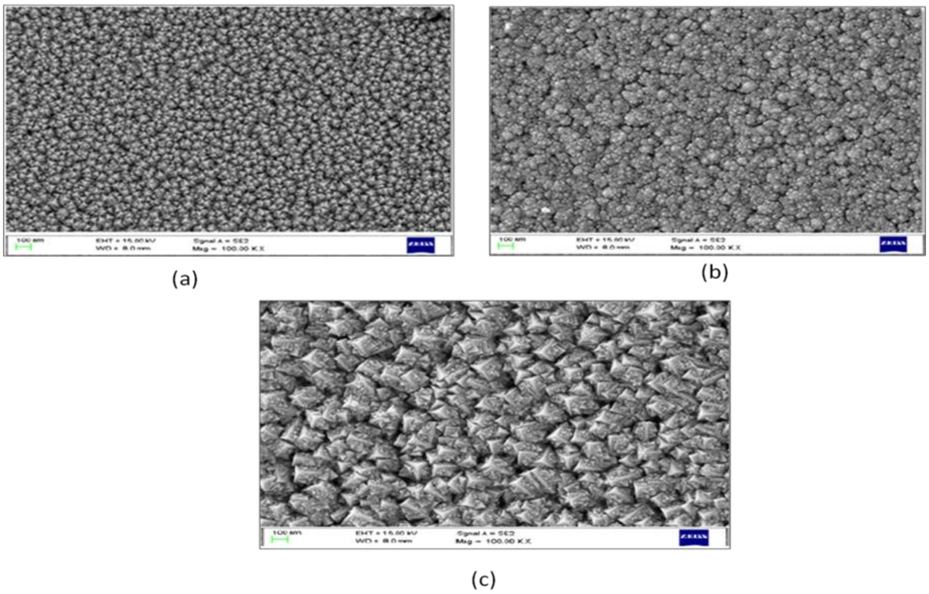

Fig. 2. SEM images of film deposited at different substrate temperatures, (a) 100°C (b) 150°C (c) 200°C

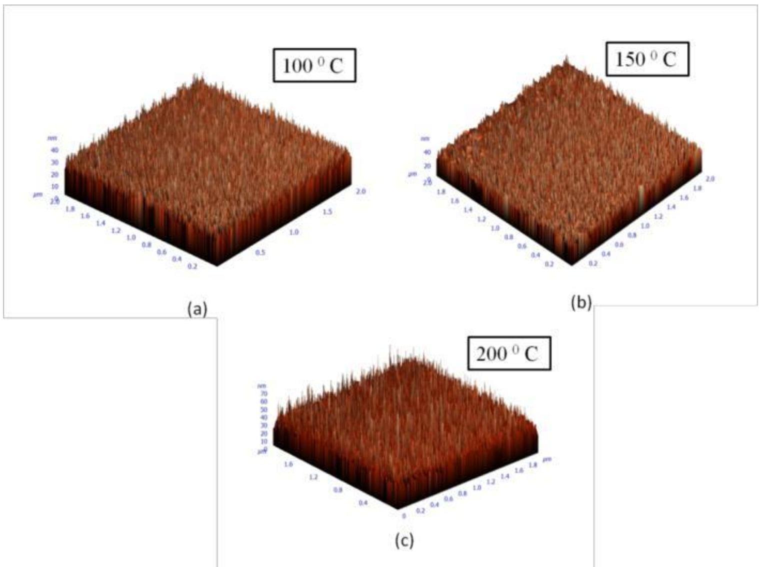

Fig. 3. AFM micrographs of film deposited at different temperatures

Table 1. EDS data of deposited CrN samples at different substrate temperatures

Substrate temperature (^{0}C)	Atomic % Cr	Atomic % N_2
100	39.56	46.54
150	40.77	44.31
200	42.06	42.48

3.4.1 Effect of working period

The results obtained during the study are depicted in Fig.5. It is clear from the figure that the weight of shovels decreased with increase in working period for all tested shovels. Shovels with different substrate temperatures coating deposited after 100 h are shown in Fig.6. This result is with the findings of [27, 28] who also reported that wear increases with increase in period of work. Wear rate was gradually increasing with time. The higher average wear rate of 2.41 mg/min was observed during 100 h of operation in non-coated shovel, and the same was reduced for 100 ^{0}C, 150 ^{0}C and 200 ^{0}C that was 2.02 mg/min, 1.77 mg/min and 1.36 mg/min respectively. This may be due to the reason that as substrate temperature increases adhesiveness of the coating increases. The results are in agreement with (Lufitha,2001) who also reported that adhesion strength of the coating increased when substrate temperature was raised.

A statistical analysis was also carried out to find the significant effect of substrate temperature based coating and time on wear of shovels (Table 2). ANOVA shows that the main effects of time and temperature were highly significant on wear loss. The analysis further reveals that the interaction S (Shovel) x t (Time) was also significant. Table 3 showing mean values interaction effect of substrate temperature based coating and time on gravimetric wear.

3.4.2 Effect of substrate temperature based coating on wear of shovels.

The cumulative wear observed was 14.48, 12.13, 10.59 and 8.15 gm for shovel with non coated and substrate temperature coating at 100 ^{0}C, 150 ^{0}C and 200 ^{0}C respectively after 100 hrs of working period. It was found that the wear loss decreased with increase in substrate temperature based coating. Minimum weight loss due to wear was observed in shovel with temperature 200 ^{0}C. Thus, with the increase in temperature from 100 ^{0}C to 200 ^{0}C the cumulative wear was decreased by 43.71 per cent. Further wear rate was calculated for the tested shovels (Table 4.). The wear rate was minimum i.e., 1.36 mg/min for shovel with 200 ^{0}C substrate temperature and for shovel 100^{0}C it was 2.02 mg/min. These results are in agreement with the findings of [29-31]. Fig.7 shows graph between wear rate and time.

Table 2. Analysis of Variance for the effect of substrate temperature based coating and time on wear of cultivator shovels

Source of Variance	DF	SS	MSS	Computed F
Shovel (S)	3	63.42	21.14136	1170.688*
Time (t)	5	1145.58	229.1169	12687.18*
Sxt	15	47.31	3.154078	174.6548*
Error	48	0.87	0.018059	1.000
Total	71			
Grand Mean		11.33		
C V		5.51		

** Significant at 5 % level*

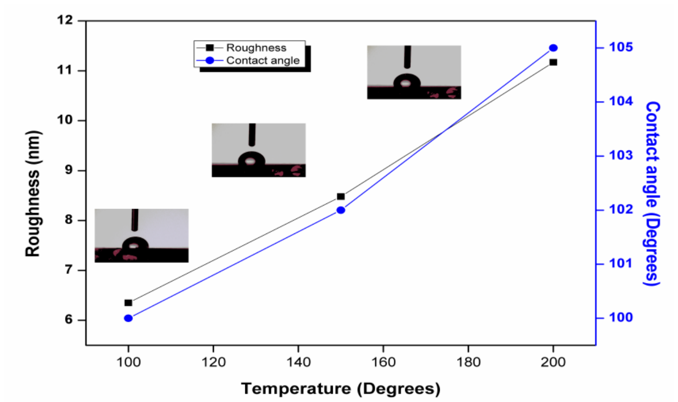

Fig. 4. Contact angle and roughness of film deposited at different temperatures

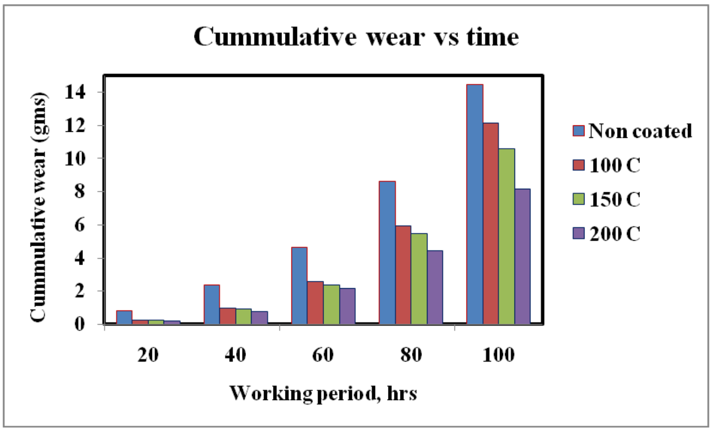

Fig. 5. Cumulative wear in shovels with different substrate temperature coating at different working period

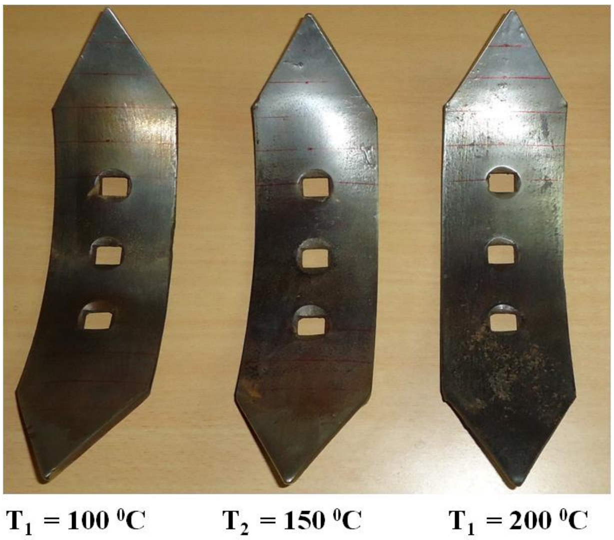

Fig. 6. Shovel with different substrate temperature coating after 100 hrs of working period

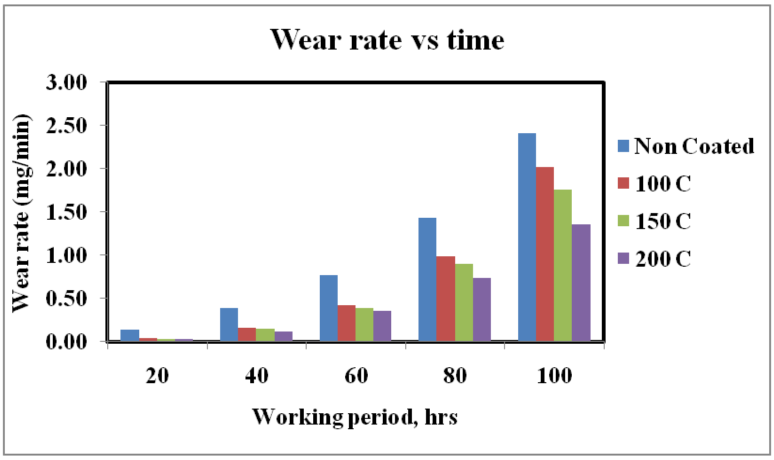

Fig. 7. Wear rate in shovels with different substrate temperature coating at different working period

Table 3. Mean values showing interaction effect (two variables) of substrate temperature based coating and time on gravimetric wear.

Time/Shovel	S_1(Non coated)	S_2(100°C)	S_3(150°C)	S_4(200°C)	Mean
0	0.00	0.00	0.00	0.00	0.000
20	0.82	0.25	0.22	0.17	0.367
40	2.38	0.95	0.89	0.75	1.243
60	4.65	2.55	2.36	2.14	2.928
80	8.60	5.92	5.44	4.41	6.090
100	14.48	12.13	10.59	8.15	11.338
Total	30.94	21.80	19.50	15.62	
Mean	**5.16**	**3.63**	**3.25**	**2.60**	

Table 4. Wear rate of shovels with different substrate temperature based coating

Sr.No.	Shovel (Temperature)	Wear rate (mg/min)
1	S_1(Non Coated)	2.41 mg/min
2	S_2(100 °C)	2.02 mg/min
3	S_3(150°C)	1.77 mg/min
4	S_4(200°C)	1.36 mg/min

5. CONCLUSIONS

The diffraction patterns confirms that the coating deposited on the shovel was chromium nitrite (CrN) and exhibits cubic structure. Crystal size was found to increase with increase in substrate temperature. Cr/N ratio was approximately one for film deposited at temperature 200^{o}C, while for other deposited temperatures at 100^{o}C and 150^{o}C and it was less than one. Roughness value was found to increase with temperature. Water contact angle were observed 100^{0}, 102^{0} and 105^{0} at 100 ^{0}C, 150 ^{0}C and 200 ^{0}C substrate temperature respectively, which confirms that CrN coating was hydrophobic in nature. The effect of temperature was found significant and the wear loss decreased with increase in substrate temperature coating. Minimum weight loss due to wear was observed in shovel with maximum substrate coating temperature at (200 ^{0}C). The shovels with different substrate coating temperatures wore along the thickness. There was negligible change in length and width. The reduction in thickness in all shovels followed the same pattern. Wear loss was maximum at the tip of the shovel and it gradually decreased while moving away from the tip of the shovel. Minimum dimensional wear loss was observed in shovel with substrate coating temperature at (200 ^{0}C). On the basis of the above findings, it was concluded that the DC magnetron sputtering coating technique can be used to deposit antiwear, corrosion free and hydrophobic coating at 200 ^{0}C substrate temperature on agricultural tools. The working life of the agricultural tool can be increased upto a significant level by depositing the desired coating on the substrate.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Singh S, Singh RS, Singh SP. Farm Power Availability on Indian Farms, Agricultural Engineering Today. 2014;38:44-52.
2. Owsiak Z. Wear of symmetrical wedge shaped tillage tools. Soil Tillage and Research. 1997;43:295-308.
3. Gupta AK, Jesudas DM, Das PK, Basu K. Performance evaluation of different types of steel for duck foor sweep apllication, Biosystems Engineering. 2004;88:63-74.
4. Ferguson SA, Fielke JM, Riley TW. Wear of Cultivator Shares in Abrasive South

Australian Soils. Journal of Agricultural Engineering Research. 1998;69:99-105.
5 Karoonboonyanan S, Salokhe VM, Niranatlumpong P. Wear resistance of thermally sprayed rotary tiller blades. Wear. 2007;263:604-608.
6 Karamis MB. Energy losses resulting from tillage tool wear in Turkish agricultural fields. In: Third International Symposium Ismir, Turkey, October 26-29, Mechanization and energy in agriculture, Proceedings. 1987;211-219.
7 Lin J, Sproul WD, Moore JJ, Lee S, Myers S. High rate deposition of thick CrN and Cr_2N coatings using modulated pulse power (MPP) magnetron sputtering. Surface and Coatings Technology. 2011;205:3226-3234.
8 Jagielski J, Khanna AS, Kucinski J, Mishra DS, Racolta P, Sioshansi P, et al. Effect of chromium nitride coating on the corrosion and wear resistance of stainless steel. Applied surface science. 2000;156:47-64.
9 Lukaszkowicz K, Dobrzański LA, Zarychta A, Cunha L. Mechanical properties o multilayer coatings deposited by PVD techniques onto the brass substrate. Journal of Achievements in Materials and Manufacturing Engineering. 2006;15:47-52.
10 Dobrzański LA, Gołombek K, Mikuła J, Pauma D. Multilayer and gradient PVD coatings on the sintered tool materials. Journal of Achievements in Materials and Manufacturing Engineering. 2008;31:170-190.
11 Pakuła D, Dobrzańsk LA. Investigation of the structure and properties of PVD and CVD coatings deposited on the Si_3N_4 nitride ceramics. Journal of Achievements in Materials and Manufacturing Engineering. 2007;24:79-82.
12 Dobrzański LA, Wosińska L, Gołombek K, Mikuła J. Structure of multicomponent and gradient PVD coatings deposited on sintered tool materials, Journal of Achievements in Materials and Manufacturing Engineering. 2007;20:99-102.
13 Gulizia S, Jahedi MZ, Doyle ED. Performance evaluation of PVD coatings for high pressure die casting, Surface and Coatings Technology. 2001;140:200-205.
14 Jellad S, Labdi C, Malibert G, Renou G. Nanomechanical and nanowear properties of Cr_3C_2 thin film deposited by RF sputtering, Wear. 2008;264:893-898.
15 Esteve J, Romero J, Gomez M, Lousa A. Cathodic chromium carbide coatings for molding die applications, Surface and Coatings Technology. 2004;188:506-510.
16 Roy M, Pauschitz A, Polak R, Franek F. Comparative evaluation of ambient temperature friction behavior of thermal sprayed Cr_3C_2 - 25(Ni20Cr) coatings with conventional and nano-crystalline grains, Tribology International. 2006;39:29-38.
17 Dave V, Gupta HO, Chandra R. Nanostructured hydrophobic DC sputtered inorganic oxide coating for outdoor glass insulators, Applied Surface Science. 2014;295:231-239.
18 Warcholinski B, Gilewicz A. Tribological properties of CrNx coatings. Journal of Achievements in Materials and Manufacturing Engineering. 2009;37:498-504.
19 Gulizia S, Jahedi MZ, Doyle ED. Performance evaluation of PVD coatings for high pressure die casting, Surface and Coatings Technology. 2001;140:200-205.
20 Ferguson SA, Fielke JM, Riley TW. Wear of Cultivator Shares in Abrasive South Australian Soils, Journal of Agricultural Engineering Research. 1998;69:99-105.
21 Karamis MB. Energy losses resulting from tillage wear in Turkish agricultural fields. In: Third International Symposium Ismir, Turkey, October 26-29, Mechanization and energy in agriculture: Proceedings. 1987;211-219.
22 Owsiak Z. Wear of spring tine cultivator points in sandy loam and light clay soils in southern Poland. Soil and Tillage Research. 1999;50:333-340.
23 Fuentes GG, Rodriguez R, Avelar Batista J, Housden C, Montala J, Carreras F, Carreras LJ, Cristobal AB, Damborenea JJ, Tate TJ. Recent advances in the chromium nitride PVD process for forming and machining surface protection, Journal of materials processing technology. 2005;167:415-421.
24 Musameh SM, Jodeh SW. Tribological behavior of chromium nitride coating by unbalanced magnetron sputtering, Journal of Active and Passive Electronic Devices. 2007;2:93-103.
25 Lufitha M. Effect of Substrate Temperature on Coating Adhesion. Pub. Phd. Thesis. University of Toronto, Canada; 2001.
26 Hubbard CR, O'Connor BH, International centre for diffraction data (ICDD); 2002.

27 Rubiniec MP, Dobrzanski LA, Adamiak M. Comparison of the PVD coatings deposited onto plasma nitrited steel, Journal of Achievements in Materials and Manufacturing Engineering. 2010;42:172-179.
28 Richert M, Mazurkiewicz A, Smolik J. Chromium carbide coatings obtained by the hybrid PVD methods. Journal of Achievements in Materials and Manufacturing Engineering. 2010;43:145-152.
29 Rubiniec MP, Dobrzański LA, Adamiak M. Comparison of the adhesion and wear resistance of the PVD coatings. Journal of Achievements in Materials and Manufacturing Engineering. 2007;20:279-282.
30 Chahar VK, Tiwari GS. Effect of soil moisture content on wear characteristics of reversible shovels of tractor drawn cultivator, Journal of Institution of Engineers India. 2008;46: 3-4.
31 Chahar VK, Tiwari GS, Verma RN. Wear characteristics of reversible shovels of tractor drawn cultivator, Journal of Agricultural Engineering. 2008;46(2009) :17-24.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/86000