Property Analysis of PVD Deposited DLC, TiAlN, CrAlN, TiN Coating on Gray Cast Iron

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Abstract—. Although the wear of materials are inevitable, it should be minimized as far as possible. Diamond like Carbon (DLC), Titanium Aluminium Nitride (TiAlN), Chromium Aluminium Nitride (CrAlN). DLC coatings are often used to prevent wear due to its excellent tribological properties. Aluminum Titanium Nitride (AlTiN) or Titanium Aluminum Nitride (TiAlN) is a thin film coating that was developed from Titanium Nitride. TiAlN offers higher temperature resistance than TiN. CrAlN performs well in corrosive environments and in sliding wear applications. Chromium Aluminium Nitride (CrAlN) offers greater temperature resistance than TiN and is an ideal choice in high temperature environments. This paper compares the wear resistance capability of PVD deposited hard wear resistant coatings (DLC, TiAlN, TiN, CrAlN) on gray cast iron. This paper also studies the influence of these four coatings on micro hardness property using gray cast iron as the substrate.

Index Terms—Wear resistance, abrasion, Diamond Like Carbon, Titanium Nitride, Chromium Aluminium Nitride, Titanium Aluminium Nitride.

I. INTRODUCTION

Gray cast iron is a type of cast iron that has graphitic microstructure. It is named after the gray colour of the fracture it forms, which is due to the presence of graphite.It is the most common cast iron and the most widely used cast material based on weight. Gray cast iron with its evenly distributed lamellar graphite dampens sound waves and is corrosion and wear resistant. The areas of application for gray cast iron products extend from heavy components for frames, gearwheels and gearboxes, driving castors and pulleys, engine and cylinder blocks of combustion engines to brake discs, brake cylinders and furnace components, as well as pipes, fittings and other parts with rotational symmetry.Although wear is inevitable it should be minimized as much as possible. Coatings are usually done on materials to improve properties like corrosion resistance, wear resistance, hardness, surface roughness etc.

G. Cueva, A Sinatora, W.L Guesser and A.P Tschipschin studied about the wear resistance of gray cast iron andcompared the results obtained with a compact graphite iron. He concluded that the wear of compact graphite iron is higher than that of gray irons. Practically the same friction forces and temperatures were observed, while compact graphite on the other hand showed greater friction forces and temperatures than those observed in gray irons as well as greater mass losses than the three gray irons at any pressure applied[1].M. Heck, H.M. Ortner, S Flege, U Reuter, W Ensinger reported that although Compacted graphite iron has an increased strength over gray cast iron the wear resistance of compacted graphite iron is more than gray cast iron and this is due to the formation of MnS-layer on the surface of gray cast iron. The MnS-layer which is formed acts as a lubricant which is the reason for the greatly reduced wear in case of gray cast iron. This layer is missing in the case of Composite graphite iron since the sulfur content of this alloy is about ten times lower than the sulfur content of conventional cast iron and hence the formation of Mn-S inclusions does not occur [2].

Julio Cesar Klein das Neves, Cristiane Martins Angelo,Roberto Martins Souza, AmiltonSinatora have reported that gray cast iron, is used for manufacturing components such as gears and cams, especially due to its good mechanical properties, as well as low production cost [3].Mohamed Kchaou, Amira Sellami, RiadhElleuch, Harpreet Singhhave reported that although the wear of the brake padis inevitable, it should be minimized as far as possible [4]. L.A Dobrzanski, M Polok, P Panjan, MAdamiaka have reported thatcovering tools with the thin wear resistant PVD and CVDcoatings is currently the commonly used method to extend theirlife. The PVD coatings have become the extremely important technological materials for several industrial applications and these coatings are successful in working processes at elevated temperatures. The PVD hard coatings are known for providing surfaces with enhancedtribological properties in terms of low friction and higher wear resistance [5].

A Hernandez Battez, R Gonzalez, J.L.Viesca, Fernandez Gonzalez,m.Had field have reported thatapplication of coatings on tools and machine elements is very efficient way of improving their friction and wear resistance properties in wide range of applications. Physical

Vapour Deposition (PVD) coatings are frequently used in machine elements, cutting and forming tools to improve their tribological behaviour. The properties of the coating (such as hardness, structure, chemical and temperature resistance, adhesion) can be accurately controlled. Physical vapour deposition coating is gaining in popularity for many reasons, including that it enhances a product's durability. In fact, studies have shown that it can enhance the lifespan of an unprotected product tenfold.TiN coatings obtained by this technique are used in steel cutting tools for high-speed applications. This type of coatings has good friction and wear reducing proper- ties and also offers good surface finish and corrosion protection [6]. L.A. Dobrzanski, L.W. Zukowskaa, J. Mikua, K. Golombeka, D. Pakulaa, M. Pancielekob have reported that relatively high micro hardness values were measured for the PVD coatings. This property was credited with the main influence on the wear resistance. In case of the CVD coatings the micro hardness values of coating and substrate demonstrate the biggest differences [7].

T Haque, Ertas, A Ozekcin, H.W Jin, R Srinivasan have reported that Diamond-like carbon coatings have gained appreciable acceptance in various industries (e.g., automotive, medical, tooling, components) on account of several attractive properties, including low friction and wear reduction. Diamond-like carbon (DLC) coatings have attracted a lot of interest because of their low friction coefficient, high hardness, good wear resistance and protection of the uncoated counter surface [1]. These advantages and potentials make them suitable for many tribological applications in mechanical systems. In recent years, various DLC layers have been developed by many researchers, and application examples of them have been increased for improving working efficiency and durability of machine elements, especially for automotive machine compo- nents such as valve train tappets, gears, piston pins, etc[8].

DLC coatings have the potential to reduce the wear and corrosion.DLC is very resistant to abrasive and adhesive wear making it suitable for use in applications that experience extreme contact pressure, both in rolling and sliding contact. DLC is used in bearings, cams, cam followers, and shafts in the automobile industry. The coatings reduce wear during the 'break-in' period, where drive train components may be starved for lubrication. DLCs may also be used in chameleon coatings that are designed to prevent wear during launch, orbit, and re-entry of land-launched space vehicles. Diamond Like Carbon coatings offer a hard, wear resistant, inert and low friction surface engineered solution to enhance implant performance. A variety of methods are used to deposit DLC coatings, the most common being variations on CVD (Chemical Vapour Deposition) and PVD (Physical Vapour Deposition). Traditionally CVD processes typically take place at high temperatures upto 800-900 degree Celsius, depending on material. DLCs have a temperature dependency in both service and deposition, where the tribologicalpropertiesstarttodegrade (higher friction, morerapidwear)atelevated temperatures(>200˚C) [9].

Coating exhibits high hardness, high oxidation stability, low thermal conductive and relatively low coefficient of friction against steel and other materials.The surface is the most important part of any engineering component. It is well known that most components failfrom surface initiated defects such as wear, corrosion,fatigue or fracture.Titanium nitride (TiN) films exhibit a unique combination of high hardness, chemical and metallurgical stability, excellent wear resistance, beautiful lustrous color, and a vast range of optical and electronic properties, with numerous applications in semiconductor-device technology and microelectronics, and are considered as good candidates for biomedical purposes such as coatings for cardiovascular and dental prostheses and orthopedic implants[10].The use of hard coatings (such as TiN) to producewear resistant surface layers which increase tool life time or efficiency is now well excepted although the wear performance and the corresponding wear machines stillremain under as there are many tribological systems thatthe hard coatings can encounter.Titanium nitride coatings have low coefficient offriction, high hardness, resistance to corrosion and adhesive wear. Titanium nitride (TiN) coatings deposited on cutting tools and other material surfaces susceptible to wear, help to extend the operating life and range of conditions for which they are used[11].

Chromium aluminium nitride (CrAlN) coatings are widely used for the improvement of surface hardness, wear resistance and tool life. CrAlN coating has high hardness and oxidation resistance, with applications for use with cutting tools. Chromium based coatings are a promising choice for components. These coatings combine good wear properties and a high corrosion resistance. Thin film coating applied by environmentally safe, Physical Vapour Deposition (PVD) vacuum system and this coating can be applied to most metals to provide enhanced surface characteristics, and can also be applied to some ceramics and plastics. It has the appearance of metallic silver, but is an ultra-hard material. Especially, the ternary system chromium aluminum nitride is of high interest for tool and component applications.TiAlN coatings obtained by physical vapor deposition (PVD) techniques were widely applied to improve the lifetime and performance of a wide variety of tool materials for their attractive properties such as high hardness, good wear and chemical stability [1–3]. Recently, a new ternary nitride CrAlN with higher percentage of aluminum has become the subject of ever-increasing interest coating for their excellent properties particularlyunder the high temperature condition Chromium aluminum nitride shows high oxidation resistance next to improved wear resistance [12].

The high wear resistance, the well-known deposition technique at low temperatures (physical vapour deposition, PVD) and the capacity to reduce the friction coefficient is the main advantage of chromium Aluminium Nitride coating [12].Machining tools such as drills, hobs, mills, and cutting inserts are widely coated with titanium nitride (TiN) to improve the wear resistance and durability of machining tools because of their hardness of 20 GPa. However, one of the main drawbacks for TiN is its limited oxidation resistance at high temperatures (500–550 ◦C) that can be reached during machining processes. Recently, light metal element, such as aluminium, was incorporated into the TiN forming a titanium–aluminium–nitride (Ti–Al–N) to overcome its shortcoming of instability at high temperatures. Besides higher values of hardness (>30 GPa), Ti–Al–N are superior to TiN in their resistance against oxidation at elevated temperatures. At high temperatures, aluminium forms a stable oxide of Al2O3 upon exposure to oxidizing conditions, thus protecting the underlying Ti–Al–N layers [13].

The methodology for the thesis was structured with the help of the knowledge from the literature review. The thesis is supposed to be started with the specimen preparation. DLC, TiN, TiAlN and CrAlN coating on gray cast iron is to be done by physical vapour deposition process and a comparative wear resistance, surface roughness and micro hardness analysis of these coatings and uncoated gray cast iron is to be done.

II. EXPERIMENTS

A. Micro Hardness Test (ASTM E-384-10)

Vickers hardness test were carried out on the specimen at room temperature

VHN= (1.8544*P)/(D^2)
Where,
P= load applied, 100gm
D= diagonal length of indentation

Table I Comparison of hardness

COATING	HV VALUE
DLC	683
TiAlN	628
TiN	587
CrAlN	551
GCI	523

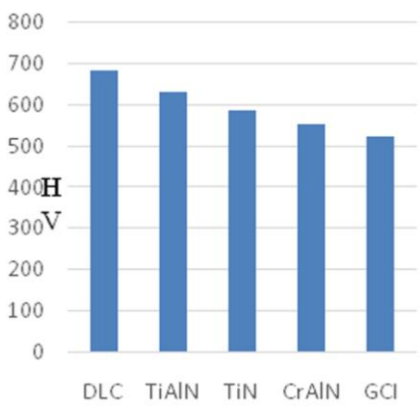

Fig. 1 hardness value comparison

From the Vickers hardness test done, it is observed that DLC offered the highest hardness value as compared to other three coatings.The next highest hardness offered coating is TiAlN, then CrAlN and the least hardness value observed was for TiN

B. Dry Sand Abrasion Test, ASTM G65

The Sand Abrasive wear Tester was used to investigate the abrasive wear characteristics of the specimens. The abrasive wear test specimens of size 75 x 24 x 8 mm were made flat on either surface by milling. The tests were carried out as per ASTM G-65 standards. The sand abrasion tester consisted of a rubber beading around the circumferential periphery of the wheel. The specimen was suitably held by means of specimen holder against the rubber wheel by means of lever arrangement. The wheel rotated (300 revolutions) and the pressure was applied by means of load (100gm) suspended over the lever arrangement. Sand held in the top of the reservoir was allowed to fall through a nozzle at a constant flow rate between the rotating rubber wheel and the specimen. The rubbing of the abrasive sand particles against the specimen leads to the physical wear of the specimens. The initial and final weights of the specimen before and after the wear tests were measured. The difference of the two weights determines the weight loss which was an indicator of abrasive wear resistance.

Fig. 2 Dry sand abrasion testing machine

Table II Abrasion test result

COATING	WEIGHT LOSS (gms)
DLC	0.005
TiAlN	0.011
TiN	0.016
CrAlN	0.024
GCI	0.041

The initial and final weights of the specimen before and after the wear tests were measured. The difference of the two weights determines the weight loss which was an indicator of abrasive wear resistance. The weight loss was minimum for DLC coating

TiAlN coating proved to be next highest wear resistant coating after DLC. The maximum weight loss was for CrAlN coating. Hence the best wear resistant coating

DlC followed by TiAlN then TiN and among the four the least wear resistant CrAlN coating

III. CONCLUSION

Hardness, abrasion wear and surface roughness test of the specimens was conducted DLC proved to be the best coating with highest hardness, improved surface roughness and minimum wear. TiAlN, TiN showed the next best results. Among the four coatings CrAlN was the least effective coating. The four coatings on GCI improved the hardness, wear resistance and surface roughness of the substrate

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