CHAPTER 2 LITERATURE REVIEW

Nitride coating has been widely used for an automobile as well as cutting tool application as it has good erosion and wear properties. Coatings work as a barrier on the substrate as it gives better hardness, better corrosion as well as wear resistance \cite{58}. The sputtering process is an advisable process to apply a coating to the substrate due to process parameter and deposition parameter which can easily control and this process is also cheaper than another coating process. Ti-based and Cr-based coatings are used widely for industrial application as it has good mechanical and tribological properties \cite{58-60}.

Researchers found that Chromium nitride coating gives the best result among other coatings for industrial application as it has the least wear, higher strength, and hardness. The hardness of CrN coating has been affected by process parameter and also on the growth of deposition \cite{60-61}.

\textit{Shah et al.} \cite{60} used magnetron sputtering process for deposition of CrSiN and CrN on silicon as well as steel materials. They found columnar growth on CrSiN material as it has nano-crystalline grains of CrN. By changing crystalline sizes, it was dense with increasing nitrogen and adding few portion of Si. Surface roughness was affected by Nitrogen as it decreases with the increase in Nitrogen. For SA304 RMS was found 69 to 28 by increasing the temperature from 373 to 773 K while for Silicon it was 25 to 11.

The hardness of CrSiN coatings increases from 2392 HV to 2570 HV with an increase in Si content. Single phase CrN thin films were observed with very high N\textsubscript{2} content (above 40\% N\textsubscript{2} content) in the deposition chamber. The hardness value of Cr\textsubscript{2}N (at 30\% N2 content in the chamber) phase is higher than the CrN (above 40\% N\textsubscript{2} content) phase \cite{60-64}.
2.1 Different Hard Coating Method

Fig. 2.1 shows different PVD and CVD process. Different types of PVD process are available. In present days, Cathodic Arc Vapour and Magnetron sputtering are very popular techniques of hard coatings. Sputtering process gives perfection in a deposition as compared to other processes. Metal targets are used to apply deposition on the material. Pure metallic targets give precise coatings \[65-71\].

Coating deposition is possible in the PVD process due to condensation of ionized or neutral metal atoms. Deposition of hard coating is possible with various PVD methods. Magnetron sputtering, plasma or ion arc plating, combined arc, and magnetron are the famous techniques used for deposition of titanium, aluminium and chromium-based coatings. On the basis of plasma, position and evaporation of component, physical vapour deposition process can differentiate. A sputtering target or evaporation source from solid to vapour transit is used to perform coating on the metallic component. According to the melting point of the cathode, targets such as Al and Ti alloy evaporation of magnetron sputtering and the cathodic arc is possible. Higher energy inputs are required for PVD arc evaporation technique as compared to sputtering techniques. The smaller cathodic area is evaporated by applying higher energy inputs in the arc evaporation process. The highly ionized metal vapour is generated by plasma.
Mechanical ejected atoms are setup on the substrate material by the impact of ions in sputtering process \cite{72}.

\subsection*{2.2 Coating Material Properties and It’s Tribological Application}

\textbf{TiAlN} \cite{73}

Many applications for TiAlN coating resemble AlTiN covering. However, TiAlN is slightly a lesser amount of brittle plus much more ductile in comparison with AlTiN: this makes it better for roughing along with interrupted cut applications. Coating colour: -Gray, Blue-gray \cite{72}

\textbf{TiCrN} \cite{72}

This type of coating material is used for application of thick sheet coatings in which high service life is required. The application will be tools regarding demands of sheet metal forming. Coating colour: - Dark Gray \cite{72}

\textbf{CrN}

CrN has higher hardness even with variable deposition parameters and it has better growth of the thin film. CrN is replacement of TiN coatings \cite{60,73,81}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure2_2.png}
\caption{PVD and CVD Coating at Different Temperatures \cite{81}}
\end{figure}
Plasma CVD and activated reactive evaporation, low-temperature sputtering and high-temperature chemical evaporation methods are used for development of a hard coating for the protection of substrate e. g. TiAlN, CrN, TiC and borides as well as carbon-based nitride. For an industrial application like forming, machining, casting and wear resistance, lots of efforts have been made for improving oxidation of metal nitrides, tribological and mechanical properties. Due to its excellent wear, strength and corrosion resistance nitride- based coating like CrN, AlN and TiN are widely used in coating industry and electronics application. For corrosion and wear resistance application CrN is stable and hard coating. It is reported in the literature that if CrN coating is deposited by magnetron sputtering, it exhibits good wear, high micro-hardness, low thermal conductivity and corrosion resistance. The preferable orientation of CrN coating depends on various parameters like the thickness of the coating, coating pressure and temperature [82–84].

Components used in automotive and biomedical industries are facing problems of wear and erosion and to reduce these issues, transition nitride coatings are used. Nitride coating not only gives protection of base metal but also provides high wear resistance, higher hardness, and corrosion resistance [85–86]. For the development of hard coatings, sputtering is one of the preferred techniques as it is advantageous for controlling process parameters in a better way and it is a cheaper process as compared to RF process.

Chromium nitride coating is widely used to different nitride processes for the application of bearing, forming and cutting tools, machine parts, moulds and dies due to its excellent wear resistance, hardness, and better strength. From literature, it has been observed that microhardness of CrN coating does not vary by changes in the process parameter and reason behind is that there are minor changes in phases during the growth of coating by a sputtering method. Due to these benefits, CrN is the substitute of TiN [85–93].

The Combination of a composite material of different properties improves the performance of material and it is a great development in modern materials.
Composite material improves mechanical properties like toughness, strength, and fatigue resistance. Composite material improves the function of a base material such as chemical, tribological, electronics and optical. To meet demands for strength, stiffness and formability, bulk component is used and it modifies by adding any other material as per application. The coating is used as a sub-layer of the surface which helps to improve functional properties and this sub-layer improves wear and friction resistance of machine elements and tools. The tribological coating improves lifetime and gives other positive effects too. Improvement in wear resistance of nitride coated cutting tool helps to increase cutting speed and productivity.

Energy consumption can be reduced by reducing friction. One can eliminate the use of coolant or lubrication by reducing friction in few cases. In few applications like safety connectors, brakes and bolted joints, friction should be increased or controlled. Forming tools and sliding application performance depends on sticking tendency and counter surface material pick up tendency.

A low weight component can be designed with coating application. The weight of car engine component can be designed by increasing power to weight ratio, which reduces fuel consumption. Coating thickness is varied between microns and several millimetres. The thinnest coating can develop with atomistic techniques. To develop phase transformation, shape changes and softening of coating high-temperature deposition is required. PVD and CVD methods are successfully applied to various mechanical components due to its high flexibility and coating structure. Common nitride coating materials are used now a days are AlN, CrN, TiN etc. and carbide coating materials are WC, TiC, W2C etc. Combinations of oxide material are also used for coatings.

Proper load carrying capacity and adhesion between substrate and layer of coating is necessary to fulfil function demands. To withstand with tribological load for avoiding premature failure and plastic deformation composite material must have good load carrying capacity[^4].
Thiyagarajan Sundararajan et al. [95] focuses on the microstructural changes during the oxidation tests. High velocity oxy-fuel coating of 50Ni-50Cr applied on modified 9Cr-1Mo steel substrate for temperature range 600–750 °C as this coating material has high oxidation resistance. Formation of chromium carbide on coated surface was done during oxidation at the time of steam oxidation. With increasing duration and magnitude, the formation of chromium carbide was increased and it also increased microhardness of the substrate material. It has been observed with a microstructural examination that by adding chromium carbide, a microstructure of substrate transformed from tempered martensite to ferrite microstructure. Formation of ferrite structure exists due to carbon depletion occurrence.

Thermal spray coatings were deposited out using an HVOF spray process (JP5000, Praxair, TAFA), which utilize the supersonic jet generated by the combustion of the kerosene-oxygen mixture. Prior to the coating process, the specimens were sandblasted using alumina powders for better adhesion of the sprayed coatings to the substrate. Six passes were adopted including the two pre-heating passes for preheating the substrate. The thickness of the coating obtained was about 60 mm. The coated specimens were supplied to X-ray diffraction (XRD) and scanning electron microscope (SEM) investigations before placing them into the steam oxidation chambers. Steam oxidation tests were carried out at different temperatures viz. 600, 650, 700, and 750 °C.

The sample pieces were taken out after different durations namely 36, 360 and 3600-kilo seconds (ks) of steam oxidation test. The surfaces of oxidized specimens were analysed by XRD to identify the new phases formed during steam oxidation in comparison with the as-coated conditions. Backscattered electron image (BSE) and electron probe microanalysis (EPMA) studies were carried out on the cross sections to reveal their change in morphology and the elemental distribution of the coating after the steam oxidation [95–96].

K. Polychronopoulou et al. [97] applied transition metal carbides by short bands which are widely used for wear-resistance material like cutting tools due to its excellent properties such as strength, hardness, chemical and thermal stability.
Hard carbon-based coating deposition by sputtering is one of the classes of metal coating which contain pure metal cathodes. Hydrocarbon or inert gas mixtures used in this type of coating where the reaction occurs between the gas phase and metal atoms. Generation of radial hydrocarbon and ionic species occur due to the existence of plasma discharge.

Development of wear-resistance and the tough coating is possible from last few years due to advancement in coating deposition technology. Crystalline carbide coating like WC and TiC is used in diamond-like carbon matrix coating which comes in the amorphous category. A composite coating which is based on metal-metal coating is also a new concept of coating which provides ceramic values of hardness and low coating elastic modulus.

It has been observed that it is possible to achieve hardness nearer to ceramic and low elastic module by using nitrogen, boron or carbon for PVD process. Physical Vapour deposition method gives better results in terms of tribological aspects like higher elastic modulus as compared to another coating like boride, carbide or ceramic nitride coatings. Titanium carbide coating gives good friction coefficient, low wear rates, high hardness and dense structure. For the evaluation of phase fraction, microstructure and composition X-ray photoelectron and X-ray diffraction techniques were used. It is observed that higher carbon contents gave rise to dual phase nanocomposite coatings consisting of stoichiometric TiC crystallites and free amorphous carbon while low carbon contents provide sub-stoichiometric crystalline TiCx coatings. At an average grain size of fifteen-nanometre, optimum performance observed for Titanium chromium nitride coating which can separate DLC matrix in two-three monolayer[97–107].

Hooshang et al. presented coating system used for foil bearings that can sustain for higher temperature and higher operating speed. This type of coating is applicable for gas turbine engine application. For the implementation of best coating combination tribological performance of various coating was done at high temperature and high speeds. Inconel was used as a substrate material which can represent as apportion of foil bearing and various Korolon TM coating was applied to it. Korolon TM, plasma sprayed, hard chrome and dense chrome were
used for coating counter disk. For high temperature and high-speed foil bearing application, Korolon TM coatings performed well for tribological aspects. Tribological behaviour of the coating was verified by using temperature as a function and it is observed that during start-up and shut down period coefficient of friction was less than 0.1 observed[108].

2.3 HVOF Coating

HVOF coating is used for industrial application as it can work with high velocity and varied temperature range. Application of HVOF coating has been used for metals and alloys coatings like nickel, stainless steel and WC-Co types of coatings. HVOF coatings depend on various coatings parameters and this parameter gives effects on hardness and microstructure. The velocity of coating powders depends on chamber pressure. The growth of coatings has been affected by process parameters like particle velocity. These types of coatings are widely used in automobiles and boiler applications[109–111].

As compared to plasma methods and conventional spray coating method, High Velocity Oxy-fuel coating techniques provide superior property layers. In this, processed powder at high speed thrown on the surface to be coated and without affecting the base, fully dense layer can be generated with the benefits of this process good adhesion, fine surface finish, a higher density of layers, high rate of deposition and deposition of a thick layer with better adhesion is possible. For the purpose of applied coating on carbides and metal alloys high-velocity plasma spraying powder and flame was used. High-quality powder material from ordinary stainless steel to superalloys like cobalt or nickel is used as a coating material. Proper selection of coating material in high-speed flame spraying can increase the life span of material. A few application of high-speed coating has been described below:

**Heat resistance.** Cobalt-based alloys and ceramic materials are used to provide protection against high-temperature range up to 1250 °C in reducing and the oxidizing atmosphere. Examples of heat resistance applications are annealing rings, furnace rolls, hot rolling steel, and muffle furnace.
**Wear protection.** Tungsten carbide coating with hardness is the best example of protection against high wear. Nickel chromium and other chromium-based coatings are widely used as they have a better hardness at a higher temperature up to 750 °C and also have good corrosion and higher density properties. Some examples of this type of coatings are a wire for rolling steel, impellers, wear plates, slide bearings, separators, rotary valves, shaft, fans etc.

**Corrosion Protection.** Stainless steel and its alloys are mainly affected by corrosion. HVOF coating is the corrosion resistance coating for such metals. These types of coating layers are useful for surfacing and lining purposes. An example of corrosion resistance coatings are fans, tanks, and others.

B. Sun *et al.* [111] have developed high velocity oxy-fuel coating with 3 MPa pressure of combustion pressure at a lower temperature and higher flame velocity. For deposition of nickel, stainless steel, WC-Co and cement conventional high velocity oxy-fuel coating process is used as it has the moderate temperature *et al.* higher flame velocity characteristic.

In this research work, particle velocity has been measured by the DPV-2000 system. Chamber pressure was maintained between 1 to 3 MPa and during the deposition of the stainless steel, 316L powder pressure of the chamber was maintained up to 3 MPa. Microhardness, microstructure, and efficiency of deposition have been investigated. It has been observed that particle velocity was affected by the pressure of combustion pressure. By varying spray parameters partially molten and the unmolten particles can be deposited which provide dense coatings. Efficiency up to ninety per cent was achieved by optimizing spray parameters [111].

Z. Zurecki *et al.* [112] developed high velocity oxy-fuel coating with LIN cooling, higher heat input and automated cooling system for the substrate. A superior hard chrome coating technology known as high velocity oxy-fuel coating was developed to reduce the effect of toxic chromium on coatings. HVOF coating reduces coating period by 50 % and also save process gases as well as feed
powder when applying on WC-CoCr application and commercially available landing gear. As compared to conventional coating techniques, coating developed by the new cooling system has a better quality of the coating. It has also improved mechanical property of a substrate by controlling substrate temperature\textsuperscript{112–113}.

L. P. Ward \textit{et al.} \textsuperscript{114} used high velocity oxyfuel method for deposition of three types of WC-based coating on ferrite stainless steel substrates. Three types of WC-based coatings, WC-10Co-4Cr, WC-12Ni, and WC-20Cr2C3-7Ni was used by a high velocity oxy-fuel deposition process on ferrite stainless steel substrates. It was observed that WC coating deposited by HVOF method gives similar result obtained by hard chromium electroplate coatings as it has poor corrosion resistance with improvement in abrasive wear and fatigue characteristic. Corrosion resistance was improved by incorporating metallic and other binders in WC-base matrix. As compared to electroplated hard chrome coating on steel, excellent corrosion resistance is achieved by WC-Co coating developed by HVOF coating techniques. Researchers reported that by adding Cr into WC-Co based coating, it further improve corrosion resistance exposed to sea water. By increasing Co, binder level helps to reduce porosity and increased resistance. Corrosion resistance of WC-Co coating was improved by adding NiCrAl and other coating composition. WC coating on AISI 4340 high strength steel deposited by HVOF method was not corroded after 558 hours by adding WC-12Ni while WC coating was completely corroded within 72 hours\textsuperscript{114–121}.

\textbf{Advanced HVOF Technology for Superior Coating Characteristics\textsuperscript{116}}

Coatings produced using HVOF have outstanding characteristics, even above other thermal spray processes, that include:

\textbf{Hardness.} A 12\% tungsten carbide-cobalt coating has a micro hardness of 1100 to 1350 DPH300.

\textbf{Density.} Porosity noted less than two per cent for typical coating and even point five percent porosity noted with few coatings.
**Toughness.** HVOF coating can develop wear resistance coating and impact resistance at a lower temperature and short dwell time.

**Strength.** HVOF coated carbide coating can provide the excellent bond strength of 69 MPa. As compared to atmospheric thermal spray coating method like air plasma spray HVOF coating can provide higher bond strength.

**Coating Thickness.** Better coating thickness can be achieved by HVOF coating process as compared to wire coating, combustion or plasma coating process when the same coating material is used. Some tungsten carbide coatings can have a thickness greater than 6.4 mm (0.250 inches).

**Wear Resistance.** Depending on the process, parameter and material HVOF coating provide better cavitation, adhesive and sliding wear, fretting, and erosion properties.

**Stress.** HVOF coated material have low tensile stress which reduces the possibility of cracks provides better coating thickness limits. It also reduces compressive stresses.

**Surface Finish.** The coating developed by HVOF coating provides a smooth surface finish which can be used for many applications.

**Corrosion Resistance.** HVOF coating has better corrosion resistance in the atmosphere, acidic, liquids and alkaline solutions.

To control different characteristic of coating manipulation of high-velocity, an oxy-fuel coating is required. Fuel mixture like oxygen and kerosene applied in the combustion chamber. Coating powder is injected downstream from the gun and it is heated here before applied on the substrate. Partially melted powder particles are impacted on the substrate and spread over the surface of the substrate. Particle temperature and atmosphere control are done by controlling oxygen to fuel ratio in the combustion chamber. Particle velocity is influenced by feed rate, combustion chamber pressure and pressure of oxygen and fuel. Powder particles
and substrate interact to control stress within the coatings. Stress in the coating can be reduced by manipulation of these variables. Improvement in coating strength, surface condition, and residual stress ultimately improve the durability of the coating. High integrity of coating can develop with varying process parameter and different types of HVOF system [122–127].

E. U. Lee et al. [128] presented that HVOF coating reaches up to atmospheric temperature due to generated compressive stress and it also increases fatigue resistance. Compressive stress and strength can be reduced if substrate material is over tempering by heat input in HVOF process. This degradation of strength and reduced compressive residual stress may decrease the fatigue resistance and SSC. Fatigue resistance and SSC magnitude is affected by these effects. Cr plated HVOF coating performed near atmospheric condition and hence heat treated substrate is not affected. Cr plating has unconsumed tensile stresses due to a reduction in fatigue resistance. In this study, before applying Cr plating and HVOF coating, the substrate was shot-penned and compressive residual stresses were measured. As compared to Cr plated coating HVOF coating have lower residual stresses due to heat input used in HVOF coating process. By increasing heat input in HVOF coating, more reduction in SSC resistance is achieved [128–132].

2.4 Coating by PVD Method

Coatings are used for various mechanical parts as well as for machine elements like valves and bearings. Coatings improve properties of the base materials. The combination of more than one composite coating improved the functionality of base metals. Use of composite coatings improves toughness, strength, and stiffness and it also has been noted that it improves functions of electrical and Tribological.

These types of coatings improve the lifetime of metals. Following are the benefits of composite or mono coatings.
• Few applications have been affected by frictions, coatings help to improve or limiting frictions as required. Examples of this type of application are bolted joints, brakes, and connectors.
• A coating helps for reducing energy consumptions as it reduces friction and in this way it eliminates the use of lubrications.
• Wide applications of PVD coatings are cutting tools as it helps to increase cutting speed and in this way, it improves the life of the tool and productivity.
• For forming and sliding application use of coatings eliminates to apply sticking agents.
• Low weight components can be designed for coatings and it will increase power to weight ratio and in this way low weight engine manufacturing has been possible, which is helpful for lower fuel consumptions.

2.5 Review of Literature

The main objective of the contemporary machining technology is the constant increase of durability of highly efficient cutting tools manufactured by a powder metallurgy method enabling machining at a high speed. The requirement of sintered tool materials due to its better wear resistance and mechanical properties are necessary for the development of technologies and techniques. It is necessary to find out a solution for a quality of machining process and increase capacity with a reduction in material consumption and energy. By consideration of proper machining parameter, the geometry of tool and cutting tool materials manufacturing cost of machining can reduce. Hard coating deposit by PVD and CVD processes improves the properties of the tool by proper selection of cutting condition and it also eliminates the use of cutting fluid. As compared to the uncoated cutting tool, cemented carbides and cerments carbide tools increase tool life by decreasing cutting edge wear. Coated cutting tool also protect tool tip against overheating and oxidation.\textsuperscript{[132-133]}

Vikas Chawla \textit{et al.} (2013)\textsuperscript{[133]} has been focused on characterizing the thick (by plasma spraying and gas nitride) and nanostructured thin (by PVD process) TiAlN and AlCrN coating developed on ASTM-SA210 Grade A-1 boiler steel. The nano-
structured thin TiAlN and AlCrN coatings exhibit less porosity (<0.5 %) The phase identified were Al₂O₃, TiN, Ti₃Al, and AlN and small peaks of TiO₂ and Fe₂O₃ with XRD analysis. The presence of metal nitride phase indicates that the gas nitriding process has successfully produced the desired coatings. The grain size was 16 and 26 nm for TiAlN and AlCrN calculated by Scherer formula from XRD plot. The particle size has good agreement with AFM analysis reveals the result of 18 and 28 nm for TiAlN and AlCrN Coatings. The surface roughness was observed as 3.75 nm and 6.10 nm for nano-structured AlCrN coating by AFM analysis. The conventional result shows the higher roughness 10.35--15.13 μm and 11.84--15.23 μm for TiAlN and AlCrN for a thick coating. A good adhesion revealed by bond strength of 68.74 Mpa and 54.69 MPa PSI in the case of conventional TiAlN and AlCrN coatings, respectively.

Harisha et al. (2013) [134] presented cathodic arc and beam evaporation deposited TiAlN and TiN coating on a high-speed steel substrate. For the microstructural characterization, SEM in combination with EDX was used to find out composition at a different region of samples. The average thickness of TiN and TiAlN was 2.9 μm and 1.4 μm respectively. From the scratch test, it was observed that when 3.8 kg load was applied. The needle started penetrating the coating material. At 4.0 kg load, the needle completely penetrated the coating. The hardness of HSS was 7.48--7.75 GPa and TiN was 26--31 GPa. But the good adhesion and hardness were achieved by TiAlN which related 26.5--29 GPa. The value of roughness of TiN and TiAlN were equal to 0.71 μm and 0.33 μm respectively, such that cathodic arc evaporation is a better method than Ion beam depositions as it provides a more resistant coating at a lower film thickness.

Martin Sahul, Paulina Zackova et al. (2013) [135] has been worked for the comparison of oxidation resistance of classical TiAlN monolayer coating and its advanced high hard nano-structured and multi-layered nACO₃ version at elevated temperatures. Coatings were deposited onto AISI M36 HSS using unique lateral rotating cathodes process (CARC). “In Situ” XRD Analysis revealed the fact, the oxidation resistance of then ACO₃ coating is better than TiAIN. In addition TiN, adhesion layer lost its function after thermal annealing of TiAIN coating. The coating thickness increased after heating. It was caused by the formation of oxide
layers. Formation of Al₂O₃ oxide layer on the surfaces of both coatings could load to improve their wear resistance.

Xiaoli et al. (2013) [136] has been focused on checking the role of compressive residual stress by finite element modelling in enhancing the corrosion resistance of nano nitride composite coatings on steel. Two different processes that underlie pitting were observed and show that cracks initiating at the corner of pre-existing micron-scale defects and propagating along the interface, driven by the combined effect of localized shear stress and corrosion-induced weakening on the TiSiN layer, delaminating along the interface between the columnar-structured TiN and the substrate, resulting from the penetration of corrosion agent through nano-scale pin holes and fissures. The shrinkage, closure of nano-scale defects is one of the keys through which the corrosion resistance of the system is enhanced. The caution should be needed against diffusion and interfacial cracking whereas it is beneficial for corrosion resistance.

Biermann et al. (2013) [137] has been investigated the different hard coatings for micro milling of Austenitic stainless steel. The two fluted end mills of Austenitic stainless steel X S Cr Ni 18--10 (1.4301) sewed as the workpiece and the different coatings of CrN, TiN, AlCrN, AlTiN, and TiAlN should be provided. The hardness was observed as 2500, 3500, 2300, 3000, 3300, 200 for TiN, AlCrN, CrN, AlTiN, TiAlN, S304 respectively. Relating the tool resistance property is achieved when based on a power of 2 KW and scan speed of 0.030 m/s.

Vikas Chawla et al. (2013) [138] has been worked on structural characterization and corrosion behaviour of Nanostructured TiAIN and AlCrN thin coatings in 3 weight % NaCl solution. The TiAIN and AlCrN coatings were deposited on ASTM-SA 210 grade A-1 by using Balzer’s rapid coating system. Both coatings have allowed porosity less than 0.5 %. The XRD and SEM / EDAX analysis confirmed the formation of the composition of coatings. The corrosion resistance follows the sequence.

TiAIN>AlCrN> Substrate
The corrosion current densities of the films in an aerated 3 weight % NaCl solution at room temperature were found much lower than that of substrate steel. The TiAlN performed the best result for corrosion resistance.

A. I. Fernandez-Abia, J. Barreiro, O. M. Pereira et al. (2013) \cite{139} has been focused on investigating the behaviour of PVD coatings in the turning of austenitic stainless steels. The different types of coatings such as AlTiN, nACo, nACRo, TiAlCrN were deposited onto the AISI 304L substrate and then their SEM-EDAX analysis performed. The best result for turning of difficult to machine materials as austenitic stainless steels are nACO and AlTiN coatings, since they offer the best performance it also shows the best behaviour such as better tool flank wear, less tangential cutting force which keeps almost constant, lower part roughness with Ra values interior to 2 μm, even at the final stage of the machining tests. nACO as compared to AlTiN coatings was better because of the quick diffusion of aluminium towards the tool surface through the grain borders which impedes the adhesion of the stainless steel and reduces thermal conductivity.

J. D. Majumdar et al. (2013) \cite{140} has been investigated and reported wear and corrosion resistance property analysis of WC + Ni + NiCr (70:15:15) coated AISI 304 stainless steel alloys. The microstructure of the alloyed zone was defect free and dispersion of WC (on- dissolved), partially dissolved (W₂C) and Precipitates (M₂C₆) in an austenitic matrix which revealed by XRD analysis. The optimum laser processing parameters for improved wear resistance property was an applied power of 2 KW and scan speed of 0.008. The wear mechanism was predominantly rating; coefficient of friction was reduced in laser surface alloyed sample which was also responsible for improving wear resistance property. Corrosion resistance was improved due to laser surface and a maximum improvement in corrosion than TiAlN. In addition TiN, adhesion layer lost its function after thermal annealing of TiAlN coating. The coating thickness increased after heating. It was caused by the formation of oxide layers. Formation of Al₂O₃ Oxide layer on the surfaces of both coatings could load to improve their wear resistance.
J. Zimmerman, Z. Lindemann et al. (2013) [141] has been described a method of modeling by the finite element method the residual stresses induced during thermal deposition of coatings. The correctness of numerical model was verified experimentally by measuring the deflection of a real Ti coating/Al2O3 substrate sample with the Ti coating detonation sprayed it to the ambient temperature. The temperature gradient at the coating/substrate interfaces due to the particle impact energy was 220 °C/μm. After its impact particles were flattened by 56 % (from 0.05 mm diameter to 0.022 mm height). On their impact into the substrate ceramic with a velocity of 800 m/s, the deceleration of the Ti particles due to their deforming time of the order of 3800 m/s² and impinge on a Ti sublayer. They are decelerated at 2300 m/s². The radial and axial stresses are highly concentrated at the outer cylindrical surface. The magnitude of radial residual stresses in the Ti coating increases with its thickness, reaching a maximum of 200 MPa in the thickest of coating, such that the proposed numerical models well describe the process of formation of the coating and its deformation during the deposition process.

Mujian Xia et al. (2012) [142] presented generation of thermal stress in sputtered TiB2 films and also during the films cooled down due to the mismatch of thermal expansion coefficient. The coupling field quadratic element PLANE 13 was used to fabricate the combinational system model and the finite element analysis codes (ANSYS) was employed to analyse the influence of deposition temperature and cooling velocity of thermal stress. The stress increased because the bending strain caused by the rising of deposition temperature and cooling velocity added. The strain can be easy to relax on the edge of the films-substrate system; the stress distributed on the edge is lower than that at the centre. The maximum stress appeared on the edge of the film-substrate system with deposition temperature and cooling velocity of 450 °C and 3.5 W/m²C respectively.

Dobrzanski et al. (2011) [143] used cathodic arc deposition techniques for coating (Ti, Al)N and Ti(C, N) on sintered tool material like cerements carbides and Al2O3 + TiC oxide ceramic tools. Scanning electron microscope is used for metallographic analysis of coated surface. EDS X-ray energy dispersive spectrometer is used for surface distribution and microanalysis of coated
substrate. Fictional and mechanical property investigation has implemented. Surface roughness and scratch test were done on uncoated and coated material for evaluation of coating adhesion. It has been observed that coated material has compact and dense structure. For oxide ceramic material topography shows high brittleness. Gradient Ti(C, N) and multi-component coating confirm the improvement in microhardness and roughness. Microhardness has been increased up to 35 to 76% with gradient and multi-composition coating. Microhardness of the surface layer was increased due to deposition of wear resistance coating on oxide ceramic, cemented carbide and cements cutting tools. It has been found that intensity of wear decreases in machining by applying this coating on tool material.

Pramanik et al. (2011) \textsuperscript{144} applied FEM to evaluate residual stress developed in silicon-on-sapphire thin film substrate during cooling. It was observed that fracture developed near the interface and buffer layer due to stress concentration. It was found that as compared to silicon substrate more stress generated in sapphire substrate and this is the starting point for the development of defects. In the middle of processing cause of damage happens due to change of directions of normal stresses. With increasing buffer layer thickness compressive and tensile stresses were reduced.

Abrikosov et al. (2011) \textsuperscript{145} studied Ti\textsubscript{1-x} Al\textsubscript{x}N coating on alloy substrate for hard coating application. The composition took place at 10 GPa pressure as well as at atmospheric pressure, which shows a broad region and wide miscibility gap of the composition. Age hardening and a brief understanding of Ti\textsubscript{1-x} Al\textsubscript{x}N multilayer and alloy film happen with the existence of Al- content. As compared to a monolayer of TiAlN, multilayer TiAlN/TiN has excellent thermal stability and hardness and the reason behind that better influence of kinetic decomposition.

Chaiwat et al. (2011) \textsuperscript{146} deposited (Ti, Al)N film on cold-work tool steel (SKD 11) using PVD cathodic arc system. The sintered Ti-Al target with a composition of (at %) 50 Ti and 50 Al was used as a cathode. The deposition bias voltage, bias arc current and deposition time were set at 100 V, 70 A and 90 minutes, respectively. Nitrogen gas was purged into the system with the applied pressure
of 1, 1.5 and 2 Pa, respectively. After coating, the film was characterized by crystal structures and mechanical properties. It was found that all films have the same crystal structures of Ti_{0.5} A_{0.5}N and Ti_{0.5}N with the thickness in the range of 2-3 μm. Moreover, the film prepared at N₂ pressure of 1.5 Pa possesses the highest hardness (48 GPa), high adhesion strength (>150 N), and good adhesion. The difference in hardness and adhesion of the film was found to result in size and dispersion of macro particles.

Talib et al. (2011) [147] synthesis TiAlN coating on cutting tool inserts and investigate changes in microstructural properties of the insert and its effect on cutting speed. Cutting speed has been used for machining was 120 mm/min and 75 mm/min with constant feed rate 0.06 mm/rev and depth of cut 0.5 mm. Microstructural observation of turning operation has been showing that on worn surface of the workpiece and insert two-way transfer of material is possible. Abrasive wear mechanism observed and plastic flow of coating was achieved. It has been proven that during turning operation of TiAlN coated layer cutting tool at higher temperature reduction in flank wear by increasing cutting speed and this due to better oxidation resistance property of TiAlN material.

Chawla et al. (2009) [148] used glass substrate for deposition of Ti hard coating by magnetron sputtering deposition process at variable process parameters. XRD, AFM, and SEM were used for characterization of coated substrate. By increasing substrate temperature and sputtering power texture of Ti coated thin film was (1 0 0) initially and then transformed into (0 0 2) and (1 0 1) orientation. This orientation observed at a sputtering pressure of 5 mTorr and 20 mTorr respectively. Atomic Force microscopy analysis shows that with increasing pressure, power and temperature average surface roughness increased. At higher substrate temperature 500 °C, dense morphology observed by scanning electron microscope. The grain size of Ti thin film was increased by varying deposition parameters that revealed by X-ray diffraction analysis.

Holmberg et al. (2008) [149] used physical vapour deposition method for deposition of a thin hard coating on tools and component and investigated wear and friction properties. Three-dimensional finite element analysis method used for
optimization of coated surface with reference to coating fracture. Titanium nitride coating with 2 mm thickness was deposited on a high-speed steel substrate. 500 nm and 200 nm thickness were observed for between the coating layer of both high modulus bond and low modulus bond. A selected range of load was 7.5 to 15 N for simulation of principal stress through the geometry of scratch test. Tensile stress observed was 5700 MPa for the stiffer bond layer. As compared to compliant bond layer five times higher tensile stress generated in the stiff bond layer. Strain generated in the compliant bond layer was 3.5 times higher as compared to stiff bond layer.

Chandra et al. (2008) \cite{150} investigated radial, shear and thermal stress generation on silicon and glass material coated by titanium coating by ANSYS analysis. The model used for analysis was quadratic and four-node structural with axis symmetric option. Effect of thermal stress on coating properties, substrate and deposition temperature was investigated. It was observed that by increasing deposition temperature thermal stress and of titanium coating increasing which also raise young's modulus, but coating thickness has reverse effect by increasing deposition temperature. The analytical method was used for simulation of thermal stress. For a glass substrate, the adhesive strength was decreased by the high tensile shear stress of titanium coating while for silicon substrate adhesive strength was improves due to high compressive shear stress.

Yeung et al. (2006) \cite{151} studied the effect of ternary nitride coating on thermal stability at elevated temperature. Reactive sputtering techniques were used with a nitrogen pressure of 0.053 and 0.086 Pa to synthesis TiAlN coating on tool steel and glass substrate respectively. Heat treatment was given to coated substrate up to 1000 °C to improve properties. It was observed that at 0.053 Pa pressure unexpected grain size refinement occur after heat treatment. TiN/TiAlN developed fine and grain microstructure at 850 °C, which also improve the hardness of coating up to 1700 to 2300 HV.

Mikula et al. \cite{152} used high-speed steel of 304 type to deposit Ti+TiN coating by magnetron sputtering techniques. Finite element analysis method was used for investigation of stress generated in coated substrate. Results of computational
simulation were compared with experimental results of stress measured by X-ray diffraction method for coatings. It was revealed that compression stresses were developed in Ti+ TiN coating.

Brianet et al. \cite{153} deposited TiN thin coating by a physical vapour deposition method and investigated the development of thermal stresses on the substrate due to cool down temperature up to room temperature. Finite element analysis method by ANSYS software was used for evaluation of thermal stress generation of steel substrate in TiN coating and validated it with analytical calculations. Thermal stress varied with a variation in dimension and properties of the material. With increasing thermal coefficient of expansion and coating thickness, minimum stress achieved. Based on failure point of view the critical location of failure was observed between substrate and coating as at this point highest value of radial stress obtained. It was also found that due to stress concentration at the edge higher shear stress observed near edge and spoliation start from the edge of the coating. Titanium interlayer in TiN coating decreases shears stress of components because its interlayer thickness helps in reducing stress reduction. FEM analysis was implemented for an understanding of the development of thermal stress during cooling down of hard coating substrate.

Sriram et al. (2003) \cite{154} has investigated fracture generation of circumferential and cylindrical component deposited by hard coating. A finite element analysis simulation method used for evaluation of crack mechanism on hard coated substrate. Stress distribution and load vs indentation depth used to find out plastic zone development and plastic yielding mechanism. Energy release rate was counted for examining cylindrical cracks and variation in crack length and indentation depth was compare with energy release factor. Energy factor decreased at small indentation and near the indenter axis, which reveals stability of crack growth. The substrate has low yield strength eliminates crack formation when axis value increased.

Jeonga et.al (2002) \cite{155} has been investigated the mechanism of cracking in the CVD films experimentally and theoretically. The crack initiation should be started from the edge and propagated towards the center. During cooling the
compressive thermal stresses were generated and concentrated at the thick-film edge and other additional tensile stresses concentrate on circumference the FEA Results reveals the above results. This was verified by the experimental analysis of diamond films deposited on Si, Mo, and W substrates. In addition, to high thermal stresses the W substrate interfacial adhesion plays an important role. Thus, film cracking depends on the fracture strength of the film and its relative magnitude with respect to interfacial adhesion. Methods of crack suppression were suggested on the basis of this cracking mechanism: increase of film thickness and minimization of the substrate’s CTE and interfacial adhesion. The analysis was confirmed by successful suppression of cracking by application of a low-adhesion interlayer prior to deposition of the diamond film.

Fogarassy et al. (2002) [156] focused on plasma sprayed coated cylindrical component and residual stresses generated by it. The author used chromium–molybdenum–vanadium tool steel as a substrate to deposit ZrO₂ by plasma spray techniques. A numerical simulation method used to calculate residual stresses and it was found satisfactory and neutron diffraction. It is difficult to evaluate residual stresses experimentally and this model predicted the generation of residual stresses precisely.

Erkensz et al. [157] have been investigated Three commercial coatings on HSS inserts were investigated in milling, regarding their wear behaviour related to fatigue phenomena. The obtained results ensure that the coating fatigue behaviour can be predicted, determined through the introduced impact test procedure. In this way, coatings can be evaluated regarding their suitability to anticipate cutting operations with interrupted material removal.

Korshunov et al. [158] has been focused on improving the top engineered films developed by way of double stage hardening on the tool exterior layer, with nitrogen diffusion saturation and through the use of a wear-resistant finish with complexly alloyed nitrides (Ti, Cr)N while using cathode arc plasma deposit process (CAPDP). Investigated have effects on the HSS tool life involving 16 chemical elements implanted into the base surface and the ones of four ant frictional resources. Apart from, when any cutting tool is warmed under chaffing,
the oxygen-containing stages are formulated on wear surface, which protects the actual tool, stalling the change from standard to avalanche-like wear.

Jakubeczyova et al. (2012)\textsuperscript{159} has worked on two types of coatings of independent PVD technological know-how. Nanocomposite nACo finish served by advanced LARC technology had roughness parameters was 40% lesser than monolayer AlTiCrN. It is linked to the actual makeup of amorphous in addition to nano-crystalline different parts of the actual stratum plus the approach to LARC technology. Effects gained because of the pin-on-disc analyse pointed out very good adhesion attributes of the coatings in addition to small variations in the friction coefficient for both equal layers from room temp. A technical analysis of the radial turning showed that the tested cutting PM material that incorporated the AlTiCrN or nACo layers were 2 to 3 fold stronger than other material that had no such coatings. The conclusion of both equally PVD technological throughout finish depositing showed outstanding outcomes attained because of the exams showcased, although great outcomes had been likewise obtained by simply request of the nano-composite stratum nACo by simply LARC technology.

D. Y. Wang et al. (1999)\textsuperscript{160} has been worked on cathodic arc evaporation process in which density of presented ion was increased up to 55% in comparison with a typical CAE model. Macro contaminants ejected by CAE locates were decreased substantially. The dimension of peak particles was decreased up to 0.85 mm inside diameter. WC/Co substrate performs better as compared to TiAlN coated M\textsubscript{2} high-speedsteel when the same coating applied on both. Crack generation happens between the interface layer of the M\textsubscript{2} substrate while it did not happen in WC/Co substrate due to higher adhesion toughness of 47 N. To modify interface between (Ti, Al) N with M\textsubscript{2} steel, an interface layer of TiN with 0.2 mm thickness was designed. The interlayer of TiAlN/TiN improves tribological performance as it has the capacity to withstand with oxidation strike and excessive stress. It was found that with modified interface adhesion strength was 50 N.

Heinrichs et al. (2013)\textsuperscript{161} has been investigated the particular formation and also tribo films in inner sliding contact involving PVD sprayed HSS and also case
hardening steel happen to be studied intended for three unique leading rates of speed. Two unique commercial PVD coatings, TiN and also AlCrN, were evaluated along with the following conclusions could possibly be made. With moderate rate, two tribofilms are usually formed as a standalone. One composting of Mn, Si, Al and also O with the intermediate covering of Fe and another consisting of Fe, Mn, Cr and also O with the intermediate covering of Mn. High sliding speed brings about thermal softening with the substrate, which leads to layer failure and also flaking. The coating isn’t worn, is it doesn’t substrate that is limiting. AlCrN offers better substrate protection at large speeds when compared with TiN really does.

Rabinovich et al. (2002) \cite{R2002} has been worked on ‘Duplex’ films (including ion nitriding regarding HSS substrate along with consequent PVD (coating deposition) modified by a PFPE (perfluoropolyether Z-DOL) major layer are already studied. With the initial (running-in) stage with the cutting tool wear, the particular PFPE lubrication decreases the particular friction parameter along with significantly lessens the tool surface injury. The decomposition regarding Z-DOL results in a titanium-based fluoride that might enhance the particular protective ability with the surface covering. Both most of these effects significantly raise the ‘duplex’ finish wear level of resistance.

Gertha et al. (2009) \cite{G2009} has been worked cutting tools that investigate the dry cutting process of structural gear material by AlCrN coated high-speed steel and this is the most typical tool involved in tool for gear slicing. Extra stress generation, substrate topography before coating, droplets in coating and defects for instant cracks are the most important and critical parameters for implementation of coating in the application. Excessive compressive stress higher than 4 GPa developed as edges of unused teeth was not fully covered by the coating. Oxides of tribolayer depend on Mn, Cr, Fe as well as Si about the same amount. This layer helps to reduce friction between chip and tool, in spite of this, it also works as a protective layer.

Kottfera et al. (2013) \cite{K2013} has investigated coefficient of friction, thickness and adhesion properties of titanium coating with along with chromium coating on CO$_5$
metallic drill bits. KTRN, CrAlN, TiN, and TiAlN coated were deposited on drill bits. Measured thickness was 1.1 m to 2.3 m with solidity values of 34.7 GPa for TiAlN coating. The coefficient of friction was achieved was 0.82, 0.56, 0.48 and 0.58 for TiN, KTRN, TiAlN, and CrAlN coating respectively. For CrAlN and TiAlN coating coefficient of friction decreased with increasing speed, while it decreased for KTRN and TiN coating with decreasing moving speed. Least were observed for TiAlN coating at 0.15 cm/s and 0.5 cm/s moving speed while for TiN coating highest wear found at 0.15 cm/s. Highest wear rate observed for CrAlN and TiN which reveals that this type of coating exhibits lower performance as compared to other coatings.

Turgay Kivak et al. (2013) \cite{165} investigated optimum boundaries of TiAlN coated AISI 316 drill by Taguchi method. ANOVA process was used for find out experimental effects. Process parameter selected for TiAlN coated drill was 0.12 mm/rev feed rate and 18m/min cutting speed. 23 percent optimum thrust power observed. For evaluation of optimized control parameters such as thrust power and surface roughness new mono and multilayer coating need to implement.

Nickel et al. (2000) \cite{166} worked on plasma nitride coating deposited on HSS drills and evaluate it machining performance in comparison with commercially available Tin-coated drills. Plasma nitride coated Tin coating not only improves adhesion but also improve the wear resistance of the coating. Wear performance of Tin coating on pre-nitride punch proven that it was better as compared to the commercial punch.

Sveen et al. (2013) \cite{167} studied various types of coating deposited by arc evaporation process which improves adhesion property of a material such as TiAlN thin film on a substrate like high-speed steel, cemented carbide and polycrystalline cubic boron carbide. It was observed primarily that under critical load, adhesion increases in order to PCBN – HSS – CC. At secondary position composite coating develop adhesive fracture on TiAlN and PCBN. Final conclusion observed was tougher substrate occurring and no damage found after pre-treatment.
Richter *et al.* (2001)\(^{168}\) has worked on radical and selective assessment from the carbide phases within the 1-5-1-2Nb-type affordable HSS of elevated firmness was displayed. Area fractions of carbides outperforming 1μm, under 0.05μm as well as between these kinds of values were being measured with different positions on the bar cores. In each period of time, an applicable microscopically strategy and magnifications were being employed. This finding is incredibly useful in terms of optimization of the PVD parameters is anxious, the thickness distributions of Ti, as well as TiN tiers obtained inside a commercial PVD device, proved to be of Gaussian sort.

ElHakim *et al.* (2011)\(^{169}\) studied the tribological behaviour of various machining application of AISI T15 HSS solidified coatings. Four types of lowering tools used to carry out cutting test on High-speed steel. As compared to CBN coated equipment, alumina ceramic provides a longer life of substrate for machining application. At lower speed, the behaviour of both types of CBN coating performs poorly as compared to HSS tool. SEM analysis shows that poker type chips produced. From EDS and SEM analysis it was found that cutting surface of CBN equipment was worn, which happens due to abrasion of hard particles on work bits.

Reite *et al.* (2006)\(^{170}\) has become investigated PVD coatings were deposited by making use of various depositing technologies as well as mechanical components were researched. Measurements associated with hardness, rubbing coefficient, roughness as well as abrasive wear resistance ended up executed reduced the wear rate of a coating will be the better will be the protection of the cutting borders and stability of the cutting torque. TiCN, as well as AlCrN (70/30), demonstrated the most beneficial results as well as CrC, CrN as well as AlCrN (20/80) the particular worst. The adhesive wear was studied because of the flank as well as the face. Coatings such as CrC, DLC as well as WC/C possess a high inclination for cool welding with this material. Furthermore, the contrast of Cr-based coatings with various Al-content disclosed, that there cannot be detected virtually any difference in adhesive components.
Bock et al. \cite{171} applied the double treatment on tool surface for improving physical vapour deposition coated duplex thin film. Ion nitriding applied on high-speed steel by Ti and Cr- based nitride coating which involves diffusion vividness with nitrogen. TiN based triplex coating shows most effective wear performance. The ion-modified coating gives ideal effects in tool life in forms of lower coefficient of friction and amorphous structure which prevent surface damage. This coating exhibits enhancement of coated tool life.

Pilkington et al. (2013) \cite{172} applied AlCrOxN coating on M2 grade 2.5 diameter blind hole tool steel for investigation of coating firmness. A Higher number of holes drilled on AlCrON coated drills due to better coating thickness as compared to commercially AlCrN coated drills. Nitrogen and oxygen with a ratio of 0.9/0.1 performed excellently as compared to N2/O2 rate of 0.75/0.25 for M2 grade HSS drills. The highest effective slot was observed of 17. 8 slots per mm for 75 % to 25 % of nitrogen and oxygen ratio as compared to commercially available AlCrN coated drills. EDX method applied to investigate adhesion and as compared to DC films higher than 10 kHz adhesion achieved. Regarding Fe–Cr–Ni least adhesive was achieved on drills with 75 % to 25 % of nitrogen and oxygen ratio. It seems that single coating has limitation to analyse coating characteristic.

Heinrichs et al. (2012) \cite{173} has been worked on going and intermittent sliding promotes the identical type involving transfer having a central region, consisting involving mainly moved and oxidized Manganese, Silicon, and Aluminium, bonded by means of an outside region by having an oxide level with similar composition because the work materials. The particular tool surfaces are incredibly rough the particular transfer process changes a great abrasive function, transferring metallic, now generally non-oxidized, especially to be able to scratches along with other irregularities from the tool exterior. Cracking on the coating happened in tests together with TiN although not with AlCrN. The lack of significant thermal softening and only very small differences in friction coefficient produce an untouched higher weight to breaking in AlCrN by far the most likely coatings on due to this.
Leskov Sek et al. (1992) have been investigated this experiments within the cutting sides of reducing dies wear show in which TiN coatings make the life span of reducing dies triple longer. More, it has been established how the life of cutting drops dead, whether Container coated or not, is dependent upon their solidity (64-66 HRC) and far less within the provisional bone fracture toughness of steel. Cutting tool wear level of resistance cannot be described as a material home but being a property of any complex tribological technique. Yet, it is proven in which wear level of resistance depends, first and foremost, on tool material structure and it is physical (mechanics as well as temperature) as well as chemical properties.

Kopac et al. has deposited TiAlSiN, TiAlN and CrAlSiN coating by cathodic arc evaporation techniques. B1- NaCl crystal structure was observed with the orientation of (111), (200), (220) and (311) which exhibits solid solution in the coating. After annealing at 700 °C, the hardness of TiAlN and CrAlSiN were 35-36 GPa, while for TiAlN it decreases up to 26 to 31 GPa. Higher thermal stability observed for TiAlSiN and CrAlSiN coating as compared to TiAlN coating. Tool wear of TiAlN coating was higher as compared to TiAlSiN nanocrystalline coating. At cutting speed of 150 m/min and 350 m/min CrAlSiN coated cutting tool possesses longest tool life. As compared to uncoated cutting tool CrAlSiN, TiAlSiN and TiAlN coated cutting tool exhibits lifetime of cutting tool by 2.9, 4.2 and 9.5 times higher.

Grigorieva et al. (2012) has been investigated has been investigated the two types of the layer are used on cutting tools, Layered composite ceramic (LCC) and nanoscale multilayer coating. LCC use the tools and nanoscale multilayer coating using hardened steel with the dry condition as well as heat resistance to Ni alloys. The life more standard ceramics tools about 2.5 to 8.0 times. The LCC tool is used to increasing cutting cycle of 1.2 to 1.5 times as compared to uncoated and coated ceramics tools.

Biermann et al. (2013) has been worked on the austenitic stainless steel by using AlCrN and TiAlN and CrN, TiN coating materials and test the tool wear and surface quality then compare to uncoated and coated cutting tools. The AlCrN
and CrN coating materials are best for tool wear. A low hardness of TiN and CrN coated tools. Hardness values are low to not qualify for the machining operation.

Halil et al. (2013) \(^{178}\) has been worked on the substrate materials carbide cutting tools. Coating materials are using AlTiN/TiN and TiAlSiN/TiSiN/TiAlN coating. Tool wear and cutting performance were executed by the lathe machine. A carbide cutting tool performance on hardened AISI420 steel shows by its hardness of 58 HRC. A hardness of TiAlSiN/TiSiN/TiAlN coating materials has 3240 HV. Tribometer test base on the TiN coated single layer coated materials is best because the wear rate low. The better wear resistance and good adhesion of AlTiN/TiN coated tool compare to the substrate material.

Sokovi et al. (2009) \(^{179}\) has been worked on the ceramic tool by PVD and CVD deposition methods are used. TiAlN and (Al2O3+TiC) coating materials using for substrate materials. Also, investigate multilayer coating on the ceramic substrate. Surface roughness and tool life measure the coated and uncoated tool. A multilayer coated material surface roughness maximum value of Ra is 0.37 µm. A workpiece materials surface roughness was below 2.5 µm. PVD and CVD coating deposition on a substrate were found the better quality of surface roughness and increase the tool life.

Youqiang et al. (2014) \(^{180}\) studied surface textures and soft coating on Al2O3/TiC ceramic cutting tools to reduce tool wear and improve cutting performance. Comparison of dry cutting performance was carried out on WS2/Zr coated tools, conventional tools and nano-textured tools coated with WS2/Zr. It was observed that as compared to conventional Al2O3/TiC ceramic cutting tools, cutting performance of nano-texture coating and WS2/Zr composites coating was improved significantly. Tool wear, cutting temperature, cutting force and friction coefficient were reduced for nano-texture cutting tool coated with WS2/Zr composite coating as compared to the WS2/Zr coated tool without nano-textures. For the geometry, nano-texture coated cutting tool performs better as compared to other cutting tools. Cutting performance and tool wear characteristic of coated cutting tool were improve due to lubrication film of WS2 formatted between tool-chip interface, which lower the shear strength and reduced tool-chip length.
Recep Yigit et al. (2008)\textsuperscript{[181]} has worked on the carbide tool. The HTCVD through multilayer coating on substrate materials, a test on the turning on lathe machine operation at 125 m/min to 200 m/min a both cutting tool uncoated and coated cutting tools are using. Coated carbide tool has lower wear rate as compared to uncoated carbide tools. There are three or more cutting tools are using for all testing. Multilayer coated tools are best for surface quality at all cutting parameters at 175 m/min to 200 m/min in surface quality better for all three coated tools better than 125 m/min and 150 m/min. ABUE (build up edge) at the 125 m/min to poor surface quality. The final result has TiN and multilayer coated cutting tools are suitable for turning operation.

V. Fox et al. (2000)\textsuperscript{[182]} has worked on the coating MoST and Graphit-iC for importance the hardness and better wear resistance. The hard coating through good lubricants properties and low friction are main advantages. An improved cutting performance and high-speed dry condition of MoST-titanium coating an allowed the reduce lubricants quality used and more save because the other coating materials are using at that time not aging use of old oil to be clean. A dry condition in both and coating MoST and Graphit-iC are good and more improve the productivity in forming components.

Henderer et al. (2013)\textsuperscript{[183]} has been worked on the reduce friction and increase the wear resistance by using PVD deposition method with TiSiN and CrCx/a-C: H coating materials. CrCx/a-C: H a top layer deposited on TiSiN layer by sputtering methods. ACAE method was used through Ti targets and Si with Ar+N plasma deposition on substrate materials. The improved the surface finish by CAE with Ti-Si-N coating, the sputtering processes through improved.

Qin et al. (2009)\textsuperscript{[184]} has been worked on diamond coated cutting tool to measure the coating thickness and interface stress. A investigated through different coating thickness. Surface morphology and other just like wear and cutting forces. The coating thickness increased the 4 \(\mu\)m to 29 \(\mu\)m the offered on cutting force. The residual stress has an effect on the coating thickness and also the
effect on tool life. The investigated the more diamond coating thickness so tool life increase.

Thakur et al. (2014) \(^{185}\) investigated the effect of cutting speed and tool coating on the machined surface integrity of Inconel 825 with particular emphasis on white layer formation and work hardening phenomena. Three regions have been identified in the machined surface and sub-surface region namely featureless white layer, plastic deformation zone, and bulk material. The microhardness decreased from the machined surface towards the center of the cross-sectional plane, thereby gradually attaining the bulk hardness of Inconel 825. Microhardness first increased and then decreased with increase in cutting speed. Coated tool resulted in a reduction in microhardness in the surface and sub-surface region. Thermal softening of the machined workpiece was observed at high cutting speed when machining with the uncoated tool. Finally, CVD multilayer coating has a synergistic influence on the improvement of the machined surface integrity-based superalloy (Inconel 825).

Lahres et al. (1997) \(^{186}\) investigated that suitable coatings have a great potential in the dry milling of Al alloys. Partially crystalline hard coatings with "softer" morphological regions (such as WC/C, CrC/C, or TiN + MO) and super hard diamond coatings, particularly, can be recommended for such operations. Through further development and optimization of these coatings, the transfer to dry production processes will be successful. Parallel to these activities, it is necessary to promote the development of dry machining processes further. For example, an additional adaptation of the tool geometry and the cutting parameters with regard to dry machining is necessary. Adjusting the machine technology (such as chip transportation) to dry machining also has to be carried out. If these still unsolved steps are developed together and concurrently, dry machining will be implemented successfully in production in the near future.

Dobrzanski et al. (2004) \(^{187}\) worked on cremate and cemented carbide cutting tools and using PVD and CVD deposition methods. Multilayer and single layer coating deposited on coating materials TiN+multiTiAlSiN+TiN andTiN+TiAlSiN+TiN by the PVD methods. Cemented carbide tools reducing
abrasive and increase the tool life. The both tools are cermented and cemented carbide tools with the multilayer coating by PVD process improved the quality and increase the tool life and better performance.

Chuan Siowa et al. (2013) \cite{188} investigated on cermented WC substrate. Coating materials are using TiCN and ZrN, the coefficient of friction is low in TiCN compare to TiN coating. A coefficient of friction reduces and improves the abrasive wear resistance of carbides tools. For the uncoated substrate of surface roughness increases due to a high coefficient of friction, but the COF also depends on lubricants. Surface roughness is improved in the Ti cutting tools. The surface hardness, tool life of TiCN and ZrN lower to TiCN and higher TiN coating.

Wang (2000) \cite{189} investigated the effect of cutting force of hard coating surface of cutting tools. In this study in cutting force of uncoated and coated tools are different and the numerical value is also different. Coated and uncoated tools and its performance for cutting operation are affected by few the important factors of cutting force.

Dosbaeva et al. (2014) \cite{190} worked on the effect of the cutting temperature measured by the tool-workpiece thermocouple on the wear characteristics of carbide tools with the CVD multilayer TiCN/Al2O3 coating, and low content Polycrystalline Cubic Boron Nitride tools in turning hardened D2 tool steel. Friction kinetics can controls the wear mechanisms during harsh machining conditions. XPS analysis showed the formation of Ti-O and Cr-O tribo-films on the surface of the worn CVD coated carbide tool exposed to cutting temperatures up to 923°C (cutting speeds up to 100 m/min). These tribo-films were investigated at the end of the running-in period as indicated by the wear curves. The latter temperature can be considered a suitable temperature for Cr-O tribo-films to exhibit their lubrious properties. The long-term oxidation of chromium can help dissolve this oxide in alumina as an intermediate layer in the CVD coated carbide tool and improve its wear resistance. Tribo-films became ineffective at higher cutting speed up to 175 m/min and increased the temperature up to 1100 °C, and PCBN has the longer tool life due to its higher hot hardness. This was supported by the higher intensity of adhesion marks on the chip underside produced by the coated
carbide tool at this cutting speed (cutting temperature). Adhesive and chemical wear can be considered the main wear mechanisms in the used PCBN cutting tool. In high precision turning, when high dimensional accuracy is required, it is recommended to use PCBN for its lower wear rate in the early stages of tool wear (tool flank land width is not exceeding 0.1 mm).

Halil [191] worked on AISI D2 substrate material and coating material used was CrN. Wear rate finds of the substrate material. To find the wear rate of AISI D2 steel by ball rotation and the normal load was applied. The rotation and normal load and square of rotation speed are most affecting factors. When normal load and increase rotation speed apply then increase wear value and it makes a sine curve. The value of wear volume was low at speed 145 rpm to 325 rpm. CrN coating and AISI D2 substrate decrease of the groove at normal and rotation speed low.

Fernandez-Abia et al. (2013) [192] worked on four different coatings were tested, AlTiSiN, AlTiN, and TiAlCrN by PVD method. Uncoated hard metal tools were not found in the market with the cutting geometry optimized for turning of austenitic stainless steels and with a substrate of enough quality and geometry of PVD coating. However, results can be considered valuable to conclude that difficult to machine in turning operation to austenitic steel in coating nACo and AlTiN. Good tool flank wears evaluation; allow tangential cutting force which keeps almost constant, lower part roughness with Ra values inferior to 2 μm, even at the final stage of the machining tests. When comparing these two coatings, the nACo coating was superior to AlTiN coating due to its nanocrystalline structure, which favors a quick diffusion of Aluminium towards the tool surface, through the grain borders, reduces thermal conductivity.

Kovalev et al. (2010) [193] investigated on the phase of C-AlxTi1-xN and it does not depend on chemical composition but atoms and spacing in the coating. A space of coating to reduce by TiAlCrN PVD coating and AlN is increase spacing, which provides more plasticity but hardness less than that of AlTiN coating. The good hardness and oxidation stability achieved in TiAlCrN coating, but its stiffer time.
Ninga et al. (2008)\textsuperscript{[194]} studies wear behaviours of tools and analysis was occur SEM and EDX. At high temperature wear behaviour of coated cutting tools substrate material. A nano multilayer TiAlCrN/NbN coating is superior hardness around HV2000. This coating proves that oxide during friction under the cutting condition. The flank wear and chip formation are sorted out curly smoothly as the tools wear increase. This coating through and its ability a work on and wear 1000\textdegree C.

Bouzakis et al. (2007)\textsuperscript{[195]} investigated of performance coated tool and its coating thickness. TiAlN process by PVD and its parameters are achieved the film thickness for the whole process was on the basis of XRD and EDX. The coating strength and weakness properties are improved and the improved performance of coating cutting tool compared to the uncoated cutting tool.

Ghani et al.\textsuperscript{[196]} studied the performance of austenitic stainless steel. It's coating selection and the surface on machinability. Since coated surface always better and it's help of the longer tool life. A coating deposition is using PVD and it's through AlTiN coating. The texture performance of AlCrNbN coating was better than AlCrN coating texture.

Sokovi et al. (2005)\textsuperscript{[197]} worked on PVD and CVD coating. Microhardness was increased up to 110\% for TiN multilayer TiAlSiN+TiN PVD coating 80\% hardness were increasing in TiAlN PVD coating and TiN+Al2O3 CVD coating. A tribological test and mechanical defects and the crater tools face are investigated. The result is Al2O3+SiC oxide tool is better than other coated tool and other parameters are using others coating deposition method. This coating through improved the tools life and improved the quality of workpiece.

Preenge et al. (1997)\textsuperscript{[198]} studied a microstructurally dense, the highly adherent PVD-TiAlN coating can be deposited by a high ionization sputtering process. Metal-cutting tests performed in turning, milling, and drilling of several workpiece materials demonstrate the superiority of high-ionization sputtered TiAlN coating over the conventional sputtered TiAlN or ion-plated TIN coating on carbide and cement cutting tools.
Harisha et al. (2013) [199] has investigated the coating of Titanium Aluminium Nitride (TiAlN) and Titanium Nitride (TiN) has been carried out on HSS substrate. The TiAlN and TiN coatings were deposited using two types of coating methods, beam deposition and cathodic arc deposition to evaluate coating properties. The coatings were successfully developed and they were subjected to thickness test, scratch test, microstructure analysis and chemical composition test. The thickness was determined using Laboratory microscope and at a magnification of 500X. For TiN observed thickness was 2.9 microns while for TiAlN it was 1.4 micron. It can be understood from the results of the scratch test and the thickness test that cathodic arc deposition is a better coating process in comparison to Ion beam deposition coating process as it provides a more resistant coating at a lower film thickness.

Daniel et al. [200] have worked on HSS Co5 steel substrate materials by two types methods are using PVD-ARC and PVD-SARC and coating materials are TiN, TiAlN and KTRN. Find the mechanical and tribological properties of coating materials. The highest values of the hardness of TiN and KTRN coatings were 31.33 GPa and 30.42 GPa respectively. In the case of KTRN, it is about 5 GPa less than the values given by the producer. The coefficient of friction of TiN is 0.82, Coefficient of friction of TiAlN is 0.48 and coefficient of friction of KTRN are 0.56. The high Coefficient of friction for TiN and low Coefficient of friction for TiAlN achieved. The higher value can be a consequence of the higher coating roughness Ra. It can be due to different parameters of the Pin-on-disc test because the producer does not specify them. The wear was measured at sliding speed 10 cm/s in terms of volume loss. The TiN coating suffered the lowest wear. On another hand COF of TiN coating was high (0.86). It can be due to higher hardness of the TiN coating and lower hardness of the counter-specimen. The wear of the counter-specimen was not investigated. TiAlN found the more wear and lowest Coefficient of friction. High roughness and larger contact surface area of the system coating-ball are reasons of high COF of TiN coating.

Branko Skoric et al. (2011) [201] worked on the mechanical properties of coated samples were characterized Surface microhardness (HV0.03) and Nano-
hardness (load-10 mN). A hardness increase is observed for implanted samples. The wear resistance of the TiN coating was obviously improved by the presence of a nitride interlayer. The PVD coating process did not significantly change roughness. A hardness and young modules are elevated by experiment wear resistance and hard surface its formation by nitrogen implantation. This coating provides the high hardness and high critical load and also low coefficient friction and better wear resistance.

Flink et al. (2005)\textsuperscript{[202]} investigated the average hardness and young’s modulus for the reference sample, SiO2, was measured to 9.65 to 0.4 GPa and 72.31 to 1.32 GPa, respectively. For $x = 0$ and $x = 0.14$, nano-indentation gave a hardness of 31.3 to 1.3 GPa and 44.7 to 1.9 GPa respectively. The hardness was retained after annealing at 900 °C while it decreased to below 30 GPa for 1100 °C following recrystallization and W and Co interdiffusion.

Amaravathy et al. (2014)\textsuperscript{[203]} worked on HA and HA/TiO2 were synthesized by sol–gel method and deposited on magnesium alloy by dip coating process. The contact angles of both the coatings are less than $29^\circ$ which indicate that it can enhance the bioactivity and bone growth. The in vitro studies show that the HA/TiO2 and HA coating induce the hydroxyl apatite growth with different morphology. In HA/TiO2 coating, the HA particles are bigger in size and Ca/P ratio is higher than HA coated alloy. Thus, HA/TiO2 coating can enhance good bioactivity and faster bone growth as well as corrosion resistance. Mechanical studies also confirm that the bonding strength of HA/TiO2 coating is higher than HA coating. Cell culture studies show that the biocompatibility and cell adhesion on HA/TiO2 coated alloy are greatly improved.

HolgerHoche et al. (2014)\textsuperscript{[204]} used HIPIMS and DC sputtering method for TiMgGdN, TiMgYN, and TiMgN coating on the substrate. Multi-component targets used for synthesis Mg-Gd, Mg, Ti, and Y material. Grain analysis was examined by XRD and SEM studies. As compared to DC sputtering grain refinement of HIPIMS coating was two factors higher. Due to better cohesion between grains of the HIPIMS coating better hardness was observed. Corrosion resistant found for HIPIMS coated as compared to DC sputtering coated
specimen which shows the hydrophobic behaviour of a substrate coated with HIPIMS coating. Salt spray test exhibits that Gd alloy shows improvement in corrosion performance as compared to Y alloy. Hydrophobic behaviour is beneficial that it proves better corrosion resistance of TiMgGdN-DC coating.

Sakip Onder et al. (2013)\textsuperscript{205} worked on TiN and (Ti, Mg) N coating by PVD method and it's analysis by XRD methods \( AX = 0.064 \) present separating. The potential to produce HA production encouraging result of implants the body fluid.

Sen et al.\textsuperscript{206} studied on substrate materials A2391 use DC magnetron sputtering method. Coating materials are AlN+TiN and AlN+AlN+AlN. A corrosion resistance of AlN+AlN+AlN was much more than another coating. It's a loss found defect coating in structure. A defect is more after corrosion test. Defects are holes, cracks, pinhole etc.

Feng et al.\textsuperscript{207} investigated corrosion behaviour of AISI 304 stainless steel coated with DLC, CrN, and TiCN material with physical vapour deposition techniques. HCl, NaCl, and H\(_2\)SO\(_4\) aqueous environment used for corrosion analysis and it reveal that better corrosion resistance observed for all three types of coating. In all-aqueous solution, DLC coating provides better corrosion resistance. In all types of solution CrN coating exhibits better corrosion resistance than TiCN coating.

Bustamante et al. (2012)\textsuperscript{208} examined corrosion and erosion analysis of uncoated and multilayer CrN/Cr was deposited on AISI-304 stainless steel synthesized by magnetron sputtering process. It was observed that wear rate of multilayer coating decreased halt time as compared to the uncoated substrate.

Reinhard et al. (2007)\textsuperscript{209} used magnetron sputtering method to deposit CrN/NbN coating on M\(_2\) high-speed steel and 304L stainless steel substrate and compared them. Before applying the coating, pre-treatment was given to substrate with Nb ions with a bias voltage of -600 V. Defect free, dense, droplet free and clean coating observed by pre-treated HIPMS coating was found. Transmission electron microscopy’s cross-sectional examination revealed that HIPMS pre-
treated coating has higher adhesion as compared to CA pre-treated coating. For 30 nm thick Nb interlayer exhibits sharp and clearly defined an interface which further improves adhesion. Potentiodynamic polarization study involved for examines corrosion behaviour in NaCl solution. HIPIMS pre-treated substrate shows excellent corrosion performance. Passivation rate of HIPIMS pre-treated 304 stainless steel (SS) substrates was up to +1000 mv enhancement in corrosion performance by additional Nb interlayer with a lower current density of $4 \times 10^{-5}$ Acm$^{-2}$. For M$_2$ high-speed steel substrate, CrN/NbN structured layer was sufficient to protect from corrosion with the rate of passivation up to +660 mV. On both HSS and SS CrN/NbN coating passivation was not observed with CA pre-treatment.

Leoni et al. (1999)$^{[210]}$ investigated residual stress and texture growth analysis of various nitride coating deposited on AISI 304 stainless steel by reactive sputtering techniques. TiN, TiCrN, and TiN/Ti were deposited in present work. Under non-epitaxial condition sample exhibited pre-texture as like happens in other PVD layer and known FCC structure was observed for d-TiN. Orientation observed for TiN coating was (111) in main growth direction and (211) grain fraction for the secondary layer. Compressive stress produced was less than 28 GPa. Further reduction in a compressive state was observed due to buffer layer of Ti. Stress relation mechanism and different growth texture (h 0 0) were found for TiCrN coating due to residual stress of less than 217 GPa.

Soni et al. $^{[211]}$ used composite targets to synthesize TiAlN coating on a steel substrate by applying dc magnetron sputtering process. The flow of nitrogen was varied for the preparation of coating and wear behaviour was examined by ball-on-plate tribometer. A wear test against hard chrome steel balls was done at 6N and 3N load with 5 to 15 Hz frequencies. Duration for the performance of test was fixed 10 minutes and 30 minutes. Initially wear test was carried out for a short duration of 10, 30, and 60 s fixed to understand initial interaction mechanism of coating-ball interface. SEM, X-ray, and EDAX analysis applied to composition and structure, phase analysis respectively. Knoop microhardness tester was used to examine surface hardness. It was found that with increasing sliding speed peak and stable Coefficient of friction increases between ball and
coating and it decreasing with the rise in load. It revealed that with increasing sliding speed wear rate of counter body was decreased while it increased with increasing load. Abrasive wear is the only reason behind the failure of coating and for the counter body, it was due to abrasive and adhesive wear.

Bin et al. [212] reported the effect on tribological properties of titanium nitride coated mechanical parts deposited by vapour vacuum arc method with a high rate of ion implantation. Microstructure investigation was done by XRD, Scanning auger microscopy and X-ray photoelectron spectroscopy of TiN coating. Nanoindenter system and optical profilometer used to examined nano-hardness and surface morphology. Wear and ball-on-disc friction tester used to investigate tribological properties. It was observed that wear rate and coefficient of friction was decreased by 56.55% and 63.74% respectively for TiN coating. With W implantation, the friction coefficient of TiN coating decreased which reveal the existence of titanium oxides, lubricious tungsten oxides, and soft tungsten on hard phases of WN, Ti$_2$N and TiN.

Puchi-Cabrera et al. (2010) [213] presented variation in fatigue property analysis of carbon coated 316L stainless steel substrate with 2 μm thickness. Commercially known Dymon-iCTM material used for coating and method used for deposited was magnetron sputtering ion plating process. Fatigue property was examined for coated alloy and uncoated with maximum stress range of 430–520 MPa under rotating bending condition and in NaCl as well as air environment. Under the corrosive condition, fatigue properties increased due to the presence of the coating. The outcome of a result proved amorphous structure of coating, better mechanical strength, good adhesion and existence of a compressive residual stress of coated substrate.

Fernandez-Abia et al. (2013) [214] presented a methodology to evaluate the performance of PVD advanced tools for turning of difficult to machine materials. They tested four coatings: AlTiSiN, AlCrSiN, AlTiN and TiAlCrN. The analysis was developed carrying out wear tests and analysing different signals such as cutting forces, EDX analysis of inserts, part roughness and insert image analysis. Their results indicated that the best coatings for turning of difficult to machine
materials as austenitic stainless steels are AlTiSiN and AlTiN coatings since they offer the best performance.

Cheng-Hsun et al. (2013) \cite{215} used cathodic arc plasma deposition system (with a variation of the O$_2$/N$_2$ flow ratio) to synthesize different Ti–N–O films on the AISI304 stainless steel. The coating morphologies and structures were analysed by using SEM, XRD, and TEM. Authors evaluated the impact of the O$_2$/N$_2$ flow ratio on the coating microstructure and properties like wear, adhesion, modulus of elasticity and hardness. Their results showed that the O$_2$/N$_2$ ratio properly controlled at 0.25 could produce an optimal film with a dense crystalline structure consisting of TiN, anatase-TiO$_2$, andrutile-TiO$_2$ phases, showing the best adhesion strength using a standardized ball indentation method, highest nano-indentation hardness (22.8 GPa) and highest elastic modulus in comparison to other coatings.

Shujun Gaoa et al. (2013) \cite{216} worked on hard coating deposition of CrN coatings on a 304 stainless steel substrate by magnetron sputtering techniques. Electrochemical behaviour of the coating was observed by X-ray photoelectron spectroscopy and scanning electrochemical microscopy under 3.5 wt% NaCl buffer solutions. High oxygen consumption region observed when 0.9 vs SCE/V potential applied. Pitting corrosion, galvanic corrosion, and dominant mechanism corrosion were observed in the scratch test for separate cathodes and anodes.

Darjaand Marijan et al. (2004) \cite{217-218} compared the electrochemical corrosion behaviour of chromium carbonitrides (Cr-(C,N)) and chromium nitride (Cr-N) coatings produced by evaporation in a thermionic-arc ion-plating apparatus at 450 °C. Scanning electron microscopy, potentiodynamic polarization test and electrochemical spectroscopy methods used to examine corrosion behaviour. Current density VS potential graph plotted for uncoated and coated substrate and corrosion potentials ($E_{corr}$) difference were measured. It was observed that for coating $E_{corr}$ value shifted on positive potential when coating applied. For CrN coating, higher polarization, corrosion properties, and current density were observed two to six times better as compared to the uncoated substrate.
Huang and Nordin et al.\textsuperscript{219–220} investigated the failure and wear mechanism of the multilayer coating applied on milling austenitic stainless steel with cemented carbide tools. This work also presents a comparison of multilayer TiNRtAN coating with single-layered TiN and TaN. Tool-life of milling tool was affected by chips generation of cutting edge with crack interaction. Growth and nucleation of crack mechanism were presented, which exhibits benefits of multilayer coating on milling tool. Chemical and mechanical wear mechanisms were also studied. It was revealed that TaN and TiN multilayer coating performs better for milling austenitic stainless steel. As a single layer TaN observed brittle, but by combining TaN with TiN it performs as a tougher coating. The reason behind this was it has a tendency to interact with austenitic stainless steel and least cracks were formed.

Junxiao Feng et al. (2015)\textsuperscript{221–222} investigated the morphology of magnetron sputtering coated TiAlN/TiAlSiN/Si$_3$N$_4$ multilayer coatings on steel. It was observed that Si$_3$N$_4$ acts as an anti-reflective layer while TiAlSiN and TiAlN act as a semi-absorbing layer and main absorbing layer respectively. Under optimized conditions, 0.099 emittances and 0.938 absorptances were reported. XRD and SEM analysis reveals amorphous microstructure and fine-grained morphology of coatings. Thermal analysis was investigated at five variant temperature ranges of 200 °C, 300 °C, 400 °C, 500 °C, and 600 °C for two hours duration in air environment with Raman spectrography. The coating’s spectral selectivity remained stable in air for 300 h after a heat-treatment at 272 °C.

Ekada, Majumdar and Akash Singh et al.\textsuperscript{223–225} has investigated tribological properties of ZrN coatings deposited on titanium modified austenitic stainless steel substrates (alloy D-9). The coatings were deposited using the pulsed magnetron sputtering technique in the deposition temperature range 300–873 K. A comparative tribological study was performed to evaluate frictional properties of the coatings with ceramic balls and steel such as silicon and alumina nitride. ZrN coatings prepared show lower value of the coefficient of friction (COF) which is found to be the lowest with the steel ball at the higher deposition temperature. The variation in the COF obtained with the ceramic balls and steel is further
discussed in elemental distribution in the wear tracks and relation with the morphology of the ZrN coatings.

Leyland et al. (1993) [226] reported tests to solve problems relating corrosion resistance and need for support from the underlying material. So they reported tests to access the wear and corrosion performance of TiN, CrN, PAPVD coatings on phosphorous doped electroless nickel (ENiP) coated steels. They showed that this route offers a potentially cost-effective means of utilizing PAPVD ceramic films on lower grade steels. CrN/ENiP on AISI 304 Stainless steel is shown to exhibit a promising combination of wet abrasion resistance with good corrosion properties.

Rujin and Naghibi et al. [227–228] used physical vapour deposition process to deposit 2 mm thickness Ti/TiN on 316 stainless steel substrate. It was observed that TiN coating has a hardness value of 2600 VHN and (2 0 0) orientation. At 37 °C corrosion resistance of Ti/TiN coating was improved significantly. Corrosion test revealed that when sliding stopped substrate becomes passive. Better corrosion and wear resistance observed for Ti/TiN coating.

Michler and Hadi Savaloni et al. [229–230] implanted Ni thin films of 250 nm thicknesses on type 304 and 316 stainless steel and coated post-N+ ion with the affluence of 5 × 1017 N/cm² at 15 keV energy at different substrate temperatures. By means of potentiodynamic technique, Corrosion behaviour of the samples in 1.0 M H₂SO₄ solutions was investigated. XRD analysis shows that for Ni₃N (2 0 0) and for Ni₃N (1 1 1) orientation was developed, which reveals minimum grain size and surface roughness at 127 °C temperature. Corrosion current rate of SS304 was 0.56 μA cm⁻² observed while for SS316 it was 0.01 μA cm⁻² which shows good corrosion resistance. Two percent molybdenum in alloy composition shows better performance and good agreement of SS 316 which also proves that retardation of corrosion is due to the effectiveness of nitrogen.

Tuffy et al. (2004) [231] studied the performance of cemented carbide inserts with TiN coating deposited by a physical vapour deposition method. TiN coating thickness range was selected from 1.75 to 7.5 μm for cemented carbide inserts.
Rockwell indentation test applied for evaluation of adhesion and Scanning electron microscopy used to determine profile and coating thickness. To investigate peak intensity of coating thickness X-ray diffraction method used by glancing angle. Dry external cylindrical turning used for evaluation of machining performance of TiN coated WC inserts. Best turning performance was found at 3.5 μm thickness of TiN coatings. During the dry machining operation, tool life of coated tool increased up to 40-fold as compared to uncoated tool under specific turning parameters. A Higher level of compressive stress and chipping of coating at cutting edge results in coating failure of the thicker coating.

Chicot et al. (2011) \cite{232} applied nitride coating in cyanide solution on 316L steel at 570 °C for 3 h. Generation of coating involved the deposition of amorphous carbon, hydrogenated 2 μm solid lubricant with chromium carbide layer. Hardness comparison of DLC nitride coated and uncoated steel shows the excellent hardness of nitride coated DLC coating which reveals the advantage of nitriding treatment before deposition. Load VS depth curve was developed to determine the profile of microhardness. Better hardness observed for nitride coated substrate in both diffusion and white layer.

2.6 Research Gap

From the literature review, it has been observed that stainless steel is widely used for various industrial applications like IC engine, Cutting tool, boiler tubes, etc. Annealing and other heat treatment require improvement in the performance of this material and it has been observed from the literature that after heat treatment lower hardness, wear resistance, and porosity are the issues of machining and boiler industry.

- The hard coating improves mechanical, tribological and corrosion properties of the material. Researchers have applied coating at various ranges of the temperature range and with increasing temperature, it will improve properties of the material.
• Developments of various coatings on steel material by HVOF or PVD techniques improve the friction coefficient and wear resistance. This type of coating can be used as an alternative technique instead of few hazardous techniques. Nitride coating on steel material improves hardness, wear, and corrosion resistance and it also has the better thermal stability to withstand at a higher temperature.

• Reducing the size of coating powder will reduce surface roughness and further reduce manufacturing time of products. Hard coatings give strong self-lubricating effects during sliding wear tests, combining ultra-low friction with superior wear resistance.

• Development of WC coating by HVOF improves hardness; reduce porosity and surface properties as compared to Chromium Carbide coatings.

• Nitride coatings make tremendous positive changes in Tribological as well as mechanical properties of any metals.