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Advancement in cermet based coating on steel substrate: A review

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ABSTRACT

Ceramic and metals mixed phases are a category of materials known as cermet to produce materials that have the best characteristics of both such as high hardness, abrasion wear resistance, resistance to corrosion-erosion resistance and deformation resistance against high temperature. Several thermal spray procedures e.g., high velocity air or oxygen fuel, spraying by plasma, detonation gun, and other cladding techniques, such as laser cladding, Tungsten inert gas arc cladding, have been widely utilised for the cladding of cermet powders on steel in recent decades. Cermet-based coatings on steel have gained popularity in recent years as a potential approach for improving metallurgical, mechanical, corrosion, erosion, and wear properties. This paper summarises the research that has been done to create cermet coating on steel.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Materials, Mechanics & Modelling.

1. Introduction

Cermets exhibit great hardness and toughness as designed composites, which are characteristic features of ceramics (reinforcement phase) and metals, respectively (binder phase). Titanium, molybdenum, tungsten, tantalum, niobium, and vanadium carbides, nitrides, oxides, and carbonitrides are utilized as ceramic phases, while as a metallic binder molybdenum, cobalt and nickel alloys are commonly used [1,2]. Cermet coatings have its advantageous features, including as superior oxidation and wear resistance, higher refractoriness and mechanical characteristics, therefore it is commonly used for forming and cutting applications, bearings, nozzles for abrasive slurry and corrosion- erosion resistive coatings. They've also gotten a lot of notice for ballistic impact resistance [3–6]. In 1927, the first production of cermets (WCCo) was introduced, and since then, Cermets have been made with a variety of ceramics and metals to enhance their properties. Cermets based on TiC, Ti(C,N) and WC-Co with binders including Co, Fe, Mo, Ni and alloys are now employed in a variety of applications in different industries [7,8].Since the 1920s, stainless steel has been utilized for building facades and roofs. Early instances of it being utilized structurally include a reinforcing chain placed in 1925 to strengthen London's Saint Paul's Cathedral dome. Stainless steel is currently used in a variety of architectural and structural components. Steel is utilized extensively in the transportation, power, construction, and automotive industries due to its exceptional machinability, high strength, weldability, and toughness. Cermet Coatings, deposited using a variety of thermal spray methods, are a good option for wear and corrosion resistant applications. Coatings of chromium and tungsten carbides are normally adopted to enhance sliding wear, erosive & hot-corrosion resistance, as well as to reduce mating component's coefficient of friction of machinery [9,10]. Coatings of Cr-C, Ni-Cr are utilized where excellent strength, corrosion-wear resistance is required [11]. Coatings of cermet may be utilized in a range of applications due to various coating deposition and coating powder techniques. Using various thermal spray methods, a broad variety of thickness may be produced [12]. Only the heat source distinguishes the several thermal spray methods. Coating factors like as particle size and metallic binders have a significant impact on mechanical qualities such as micro hardness and strength [13]. The velocity of particles sprayed on the surface determines coating porosity and binding strength. There are two stages to a thermally distributed cermet coating. One phase is nickel chrome, which provides exceptional corrosion resistance, while the other is chrome carbide, which protects against wear, hence in applications where parts are exposed to corrosion, Ni-Cr coatings are utilized. [14]. The type of coating technique used is determined by the coating's functional requirements as well as the substrate material. The various coating methods are described as below:

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1.1. Detonation gun

This is a useful tool for developing coatings using the thermal spray process. In a regulated combination of acetylene and oxygen, a precise exact powder amount material is fed into the gun. When the combination is ignited, it reaches a speed of roughly 3,000 m/sec. The particles get energy from the high-energy steam, which has a velocity of 3–4 times that of sound. Because particles have less time to accelerate due to their rapid velocity, heat is generated, causing the particles to melt. This coating deposition method offers a strong substrate-coating powder interfacial adhesion and a low permeability. The HOVF technique has a much greater permeability value than the D-Gun process [15].

1.2. High velocity air/oxy fuel

Thermal spraying by high velocity air/oxy fuel commonly HVOF is now frequently utilised for metallic and cermet cladding on surfaces. Coatings by HVOF are often utilised in aircraft boiler's preheaters and superheaters, as well as pipe-systems and valves. HVOF has a high-volume fraction of carbide and a homogeneous structure because it employs a low combustion temperature and a short contact period between the powder and the flame [16]. HVOF coatings offer superior mechanical characteristics than conventional thermal spray methods, such as residual-stresses, bond-strength and micro-hardness. Coating thicknesses typically vary from 0.05 mm to 0.50 mm, although with certain materials and functional requirements, thicker coatings can be applied.

1.3. Plasma spray

Steel parts with high strength, as well as corrosion and erosion resistance, are generally used in production and manufacturing sectors. To enhance these characteristics, the substrate is cladded with a variety of shielding coatings which might be applied using a variety of methods, including the plasma-spray approach. Gas flows between two electrodes in this procedure. High frequency discharge causes an arc to form between these two electrodes. The arc ionises the gas, resulting in a plasma gas at higher pressure. The bond strength by this deposited coating technique is between 40 and 70 MPa, and the coating thickness can range from 50 to 500 mm Plasma spray has a greater permeability than other thermal spray methods.

1.4. Laser cladding

Cladding by high intensity laser source is a sophisticated surface modification method that is commonly used in the remanufacturing of damaged components in the petroleum, chemical, abrasive tools, and mining sectors. Rapid heating and cooling are characteristics of laser cladding. Using a high-energy laser beam, the surface of substrate may be rapidly heated to over 10^5 K and cooled at a rate of up to 10^6 to 10^7 K /s. As a result, laser cladding produces fine grains and dense cladding layers in a coating, between the coating and the matrix, metallurgical bonding can be established, resulting in good overall performance [17–20]. The impact of the production technique and powdered WC grain size on the resistance against wear of WC-Fe cermet was investigated by Zou et al. [21]. They observed that WC powder with a smaller grain size improved coating resistance against wear better.

1.5. TIG cladding

The TIG cladding technique, which uses inert gas shielding, has been shown to be very successful for changing the surface characteristics of alloy metals by controlled fusion to a necessary depth at a reasonable cost for conventional tribological needs. The major advantages of the TIG method are deep case depths generated in a short amount of time with minimal environmental harm, all while maintaining a low supplemental and production cost [22].

2. Recent trends in cermet coating on steels

TIG welding has been utilised by a number of researchers to modify surfaces. The influence of current and torch movement on the micro-structure and size of the cladding was examined. In comparison to the substrate, the cladding exhibited a significant increase in wear resistance. WC cladding was deposited on steel grade AISI 4340 using the TIG cladding technique. Microstructure and hardness of the cladding were investigated in relation to scan speed and powder content [23]. TIG cladding can be utilized to clad with powders of austenitic steel on steel having low carbon percentage, and specific constituents such as Ti, Mo& Co can be added to enhance its properties [24]. Another research used TIG as a heat source to clad AISI 1010 steel with Ni-WC powder. The influence of, current scan speed of torch and thickness of powder layer on coating hardness and micro-structure was investigated [25]. Some studies looked at the wear properties of WC, TiN & TiC, cladding on carbon steel specimens [26]. TiC powder was also coated on steel AISI 304 plates using the TIG cladding technique [27]. Another research looked at the wear performance of WC-Ti weld cladding when it was exposed to varying sliding speeds. WC-Ti cladding outperformed TiC-W cladding due to good adhesion between steel matrix and WC powder [28]. The coating structure varies dramatically as the proportion of TiC reinforcement changes, which is dependent on the melting of the TiC particles [29]. Hodgkiess et al. [30] employed the HVOF method to coat Austenitic stainless steel with a Ni–Cr–Si–B–C cermet coating. During solid–liquid circumstances, in terms of loss in material, cermet claddings have been found to outperform stainless steel. The relative impacts of erosion and corrosion were blamed for the higher material loss seen during solid-free impingement. De Souza and Neville [31] utilised the D-Gun thermal Spray technique to cermet coat WC–Co–Cr on UNS S32760& UNS S31603 a special grade of stainless steels and compare them to stainless steel, finding that the coatings gave good wear and corrosion resistance in liquid–solid impingement.

Kumar et al. [32] employed the HVOF technique to coat steels SA516Grade 70 & SAE213 T22 with nanostructured Ni–20Cr coatings. In a boiler setting, the studied nanostructured coating outperformed its traditional (micron-sized Ni–20Cr powder coating) equivalent. Shield Cr_2O_3&NiO phases are present in respective scales of oxide, as well as their superior as-sprayed microhardness, may explain why nanostructured coatings gave higher erosion–corrosion resistance under actual boiler conditions. During the erosion–corrosion phenomena, cyclic development and erosion of the oxide scale occurred for cladded specimens, steel-SA516, on the other hand, was most possibly deteriorated. When Cr_3C_2-25NiCr coating was formed on carbon steel by HVOF by Hemmati et al. [33], since these actual tensile stresses were lowered during the test, the residual stresses under compression in the HVOF cladding were large enough to postpone crack initiation and development. Under the provided test circumstances, no adhesive failure was detected, with the exception of a 1000 N loading force. Under impact stress, micro-abrasion, tribo-reaction, and plastic deformation result in the development of micro crater volumes. Crack initiation and growth addition rapidly enhance the produced volume of crater at critical load circumstances with larger forces, the force acting has a big influence on the different sorts of failures and mechanisms. Several conventional & nano coatings produced by sputtering methods under varied conditions, likeCr-Si-N, Ti-C-N-Si, Cr/CrN multi-layer, plasma sprayed Ni3Al + Ni-22Cr-10Al-1Y, HVOF sprayed Cr-Ni-Si-B-C, thermal reactive deposition Cr_7C_3 coatings and laser coating Cr_3C_2-NiCrMoNb exhibited improved characteristics [34–39].

On AISI 304 substrate, atmospheric pressure plasma spraying is used by Thi et al. [40] created Cr_3C_2-25NiCr cermet coatings. After that, the coats were sealed with an emulsified PTEE using one of 2 techniques: ultrasonic vibration or conventional impregnation. The composition of phase, porosity, surface morphology, permeability as well as the coatings' resistance against corrosion & wear, were all studied. According to the findings, in addition to carbide phases, the PTFE sealed coatings generated a PTFE phase with a crystal lattice of hexagon shaped. The coating was completely coated in PTFE. The ultra-sonic vibration method increased the porosity of the PTFE emulsion into the cladding by more than twofold, compared to the traditional impregnation method. The PTFE cladding sealed by ultrasonic-vibration method exhibited decreased permeability in a 3.5 wt% NaCl solution, greater wear and corrosion resistances than sealed by conventional impregnation method and unsealed coating. To prevent galvanising equipment components from corrosion by liquid zinc, Xie et al. [41] used HVAF to deposit FeB 30% by weight AlFeNiCoCr cermet cladding on 316L steel substrate. Powder and coating microstructures and phase compositions were studied. The coating was further tested for resistance against wear abrasion, fracture-toughness, micro-hardness, and resistance against corrosion to liquid zinc. The findings show that the coating outperforms the 316L stainless steel substrate in terms of abrasion wear resistance and corrosion resistance. When zinc gets into macro-cracks, the cladding peels off, resulting in coating failure.

Amudha et al. [42] utilised a HVOF spray method to cover a low-carbon steel substrate with a 25 percent NiCr-75 percent Cr_2C_3 cermet powder. The SEM is used to examine the coating's morphological characteristics. The Vickers micro-indentation method is used to assess hardness of the 25 percent NiCr-75 percent Cr_2C_3 coating. The coatings' microhardness, fracture toughness, and brittleness index are measured. In addition, the contact angle determined by the sessile drop technique is used to study the coating's wetting capability in sodium chloride salt solution. The contact angle of coating is 98°, which indicates that it is hydrophobic in nature. Brittleness, fracture toughness, and microhardness are all improved by Cr_2C_3- NiCr hydrophobic coatings. Kim et al. [43] utilized cladding by laser to create a WC/T-800 cermet coating layer, which they then examined for microstructure, hardness, and wear characteristics. T-800 was cast in quantity and used as a comparator. In a laser-clad WC/T-800 cermet protective film, circular WC phases in the Co matrix and dendritic laves phases were observed. The mean laves phase size in the cermet coating layer and bulk T-800 was 7.9 m and 60.6 m, respectively, implying that the cermet coating layer had a finer laves phase. The cermet coating layer with WC proved to be more wear resistant in a wear test. The laser cladded WC/T-800 cermet cladding layer showed abrasive degradation, whereas the bulk T-800 showed pulled out laves phases. Based on the aforementioned findings, the morphology of the WC/T-800 cermet cladding layer with laser cladding, as well as the relationship between it and wear properties, were investigated.

On MDN 420 alloy, Reddy et al. [44] utilised plasma-sprayed coatings of and 25% Cr_2O_3 + 70% NiCrAlY + 5 %YSZ &30% TiO_2 + 70% NiCrAlY. Hot corrosion experiments are performed at 700 °C for 50 cycles in a molten salt environment using Na2SO4 + 60 percent V2O5 salt combination. When compared to NiCrAlY-TiO2, the NiCrAlY-Cr_2O_3-YSZ coating is proven to have a protective effect. On the outermost layer of the coatings, Al_2O_3, $NiCr_2O_4$, and Cr_2O_3 oxides develop, giving the coatings resistance to high-temperature corrosion. Lin et al. [45] coated a stainless-steel substrate with WC10Co4Cr (WCC) & WC10Ni (WN) powders. In comparison to the WCC cladding, the WN cladding showed higher H/E and H^3/E^2 values, as well as stronger CE resistance at different flow velocities in NaCl medium, while having higher hardness (H) & elastic modulus (E), lesser permeability. As the flow velocity of the NaCl medium increased, both the WCC& WN claddings showed an increase in volume loss rates (VLR). Qiao et al. [46] employed the HVOF spraying technique to create three types of tungsten carbide-based cermet claddings: WC-Ni, WC-Cr_3C_2-Ni and WC-CoCr. On $HV_{0.3}$ scale 1205 was highest average micro-hardness was of WC-CoCr coating, then 1188 WC-Cr_3C_2-Ni and 1105 WC-Ni coating. Behaviour abrasion wear of tungsten carbide-based cladding under various load and sediment concentration circumstances was investigated. Results showed that when the applied load or sediment concentration rose, so did the loss rates of abrasion wear of all the claddings. Furthermore, greater microhardness coatings proved to have better abrasive wear resistance. Under the same testing conditions, the WC-based claddings outperformed AISI 304 in terms of resistance in abrasion wear by 4 to 90 times. Binder phases are extruded and removed, and also hard phases are fragmented and peeled off, to represent the abrasive wear mechanisms of the WC-based coatings.

Ribu et al. [47] utilised the HVOF process to coat WC-10Co coatings on a steel 35Cr-Mo substrate which is frequently used in water turbines, and tested them for erosion by slurry. According to the findings', rotating velocity was the prime factor in affecting coating mass loss, then impingement angle, slurry composition& duration. Thermally sprayed cermet coatings were employed by Luiz et al. [48] to increase cavitation and wear resistance of stainless steel (SS) hydraulic turbines, notably in rivers with a having sediment load high. Few cermets, on the other hand, breakdown quickly in river water, resulting in early coating failure and high maintenance costs. Furthermore, galvanic corrosion caused by the cermet's connection to an SS might hasten the coating's decomposition. As a result, the resistance against corrosion of six cermets (WC-10Co-4Cr, WC-10Ni, WC-12Co, Cr_3C_2-10NiCr, Cr_3C_2-25NiCr, Cr_3C_2-10Ni& Cr_3C_2-10NiCr) as well as the galvanic resistance against corrosion of these materials linked to CA6NM SS were assessed in a solution that approximated Madeira River water. The greatest corrosion rates were found in WC-12Co and WC-10Ni cermets, at 0.077 and 0.068 mm/year, respectively, but the Cr content in WC-10Co-4Cr (0.017 mm/year) and Cr_3C_2-based coatings (0.005 to 0.007 mm/year) caused them to erode more slowly. Furthermore, when connected to the CA6NM SS, the WC-10Co-4Cr and Cr3C2-based cermets showed minimal galvanic corrosion current, making them suitable for coating hydraulic turbines. WC-12Co and WC-10Ni coatings, on the other hand, had a more severe galvanic corrosion process, reducing their lifespan as hydraulic turbine coatings significantly.

To test fatigue life, Gonzalez et al. [49] utilised the HVOF spraying technique to apply a cermet coating consisting of WC10Co4Cr on a C45 steel substrate. Because of the cermet coating, alumina particles stuck in the steel substrate & fatigue cracks at deep notches take longer to begin after grit blasting, and as a result, the fatigue strength of coated specimens is not considerably diminished when compared to polished specimens. On the other hand, fine grinding inhibits the coat from mechanically sticking to the substrate, causing it to dislocate from the surface when subjected to high alternative stress levels. According to Huang et al. [50], sprayed thermally is a reliable method for increasing the resistance against cavitation of hydraulic flow in water devices, particularly in at the site repair scenarios. HVOF spraying was used to create a WC-Co-Cr cermet coating for use in hydraulic components. The microstructure and hardness of cavitation were measured using an ultrasonic vibrating instrument. In terms of mass weight reduction, the coating outperforms martensite stainless steel when it comes to anti-cavitation performance.

Fedrizzi et al. [51] investigated the possibility of using new HVOF cermet coatings to replace hard chrome cermet coatings. Coatings with a $75Cr_3C_2$–25NiCr composition were sprayed onto steel cylinders in earthmoving equipment using both conventional and nano-powders. Cermet coatings were evaluated in terms of behaviour to typical hard chromium coatings. Nano powder coatings exhibited a lower weight loss value than hard chrome & traditional HVOF coatings during all operating conditions. The enhanced performance can be ascribed to reduced surface roughness, improved carbide dispersion in the metallic-matrix and the minimum permeability of coating. To enhance the porosity and resistance against corrosion of the cermet (WC-10Co-4Cr) coating by HVOF on steel substrate, Hong et al. [52] employed the Taguchi approach, which comprised the S/N ratio and analysis of variance. Distance from spray, kerosene flow, and oxygen flow were the variables studied in this research. Spray distance > oxygen flow > kerosene flow was shown to be an important spraying parameter in order for the coating's porosity, with the spray distance being the only significant component. For best results, use a kerosene flow of 6.0 gph, an oxygen flow of 1900 scfh, and a spray distance of 300 mm. Another set of studies indicated that the micro-structure has a major impact on the coatings' resistance to corrosion. The coating of cermet WC10Co4Cr has the best resistance to corrosion, which achieved by utilising the best spraying conditions with the least porosity. It looks to be an acceptable substitute for harsh chromium plating.

In dry friction at different temperatures, Hong et al. [53] investigated wear characteristics of a nanostructured coating of cermet WC-Co-Cr sprayed by HVOF vs Alumina. The rate of wear for coatings grew as the test temperature rose. The main wear mechanisms of the coatings as temperature rose were extrusion distortion at room temperature, adhesion wear, carbide powder knock, and oxidizing wear at 200 °C, and a mixture of binder extrusion and fatigue deformation combined with oxidation wear at 500 °C. In a solution of alkali-sulfide. Pang et al. [54] used laser cladding to build a monolayer of micro-nano size TiC-Ni/Mo/TiN ceramic solar spectrum selective coating on a stainless-steel substrate. The optical characteristics &thermal stability of the ceramic coating were outstanding under high temperatures, according to this study. It also offers a novel approach to the future development of solar-absorbing coatings. Gaier et al. [55], current study analyses the effects of thermal treatment on a precipitated stainless steel grade 630 against a non-heat treatable steel (316L), when stainless steel is used as the ductile binder phase in a cermet structure with TiC. The two methods were first compared using 30 percent steel in both situations. A heat treatment of 1150 °C/4h for this system resulted in a considerable improvement in Vickers hardness. Furthermore, resistance to scratch was considerably enhanced. This work shows that a heat treatable binder phase may be used to make TiC-based cermets.

Singh et al. [56] studied the development and performance of a Mo_2C-based WC-CoCr cermet coating coated on 316L steel pump-impeller by HVOF thermal spraying. When compared to traditional WC-CoCr coatings, the Mo2C-based WC-CoCr coating delivers superior microhardness. The resistance to wear of 316L steel was increased by approx. 10% when a standard WC-CoCr coating was applied. The addition of 3 percent Mo_2C, on the other hand, increased the slurry erosion performance of standard WC-CoCr coatings by 69.6%. As per Bhosale et al. [57] WC-based cermet coatings sprayed thermally are broadly used in applications requiring high sliding wear resistance. The goal of his research is to see how different counter faces affect the coefficient of friction, wear factor, and coating degradation during dry sliding experiments on WC-Cr_3C_2-Ni composite coatings produced using the HVOF process. The results of the coating's testing were compared to in terms of volume loss due to wear. The pair formed by WC-Cr_3C_2-Ni cladding with Si3N4 indicated as the least friction coefficient was detected during the dry sliding operation.

Azarmi et al. [58] used a high velocity air fuel thermal spraying technique (HVAF) to deposit two types of cermet powders on an AISI 1040 steel substrate to assess resistance under cavitation erosion circumstances with added electrochemical effects. The cavitation resistance of WC-20CrC-7Ni cladding achieved 1.3 times higher WC-10Co4Cr cladding, according to the findings. The variations in cavitation resistance of two coatings may be identified by studying their structure and surface topography: The porosity density of the WC-20CrC-7Ni coat is lower and the microstructures is finer. These variations, together with high Ni& Cr content in the coating's powder (which helps to reinforce the matrix), help to improve cavitation resistance and reduce material loss. WC-20CrC-7Ni&WC-10Co4Cr claddings were tested for resistance to cavitation under cavitation-erosion situations with extra electrochemical effects by Korobov et al. [59]. Using HAVF technique, the claddings were applied on AISI 1040 steel substrates. The resistance to cavitation of the WC-20CrC-7Ni coatings was found to be superior than WC-10Co4Cr coatings. It was feasible to identify the causes for the variations in cavitation resistance of both coatings by observing the structure and surface topography: The grain structure of the WC-20CrC-7Ni coatings was finer, the pore density was lower, and roughness of surface was reduced. These changes, along with a high Cr and Ni concentration in the feed powder, improved coating resistance to corrosion, helped the WC-20CrC-7Ni coatings improve cavitation resistance and reduce material loss.

Arunnellaiappan et al. [60] created Cermet coatings on the AA5083 utilising the D gun coating process with three distinct powder combinations: Cr_3C_2-NiCr, WC-Co-Cr, WC-Co. The impact of different powder combinations on the cross-sectional microstructure, surface morphology and phase composition of coatings was studied. Major findings revealed that WC–Co and WC–Co–Cr powders created thicker coatings with substantial surface defects as compared to Cr_3C_2–NiCr powders. The use of Cr_3C_2–NiCr particles also resulted in a smooth, compact, and uniform coating. Cheniti et al. [61] came up with a novel way to solve Incompatible properties of WC-Co cermet and AISI 304 steel were mixed in the same part using the rotary friction welding (RFW) process. A ductile NiCr interlayer and a change in WC-Co cermet positioning, i.e. fixed rotational and feeding sides, were used to create the unlike interfaces. The various welding configurations generated comparable microstructure throughout the weld joints, resulting in similar hardness and elastic modulus behaviour. When the cermet was set in the rotational side and the interlayer was inserted, the simultaneous inter-diffusion of both ceramic coating (W and Co) and steel components (Fe, Cr, and Ni) increased, resulting in the emergence of a diffusion region at the weld zone. The NiCr interlayer was shown to be effective in reducing residual stresses and increasing shear strength in WC-Co cermet/AISI 304 L steel joints, making it a promising solution for the drilling tools sector.

Shi-En et al. [62] used plasma cladding process to create a ternary boride cermet coating on 304 stainless-steel. Outcome revealed that the boride cladding layer establishes a strong metallurgical connection with the 304 stainless-steel matrix, with no defects such as macro fractures or holes at the interface. The cladding layer's average microhardness was 630.4 $HV_{0.5}$, approx. 3 times more than 304 stainless steel, significantly increasing the hardness of 304 stainless steel surface. After 48 h of immersion in a 10% HNO_3 + 3% HF acidic solution, the maximum corrosion depth ratio of 304 stainless steel and the cladding layer is 77 m and 9 m, respectively, indicating that the cladding layer has superior resistance to corrosion than 304 stainless-steel. In a fused salt environment (Na_2SO_4 + 25 percent K2SO4), The cyclic hot corrosion behaviour of Cr_3C_2-NiCr deposited on Ni & Fe based superalloys was examined by Kamal et al. [11], who discovered that weight growth is minimised and the oxide scale produced on coated substrate is fracture free and huge. The Table 1 shows comparison of some research findings in the surface coating field.

Table 1
Some research findings have been tabulated below.

Authors	Coating methods	Substrate	Coating powders	Findings
Buytoz et Al. [23]	TIG	AISI 4340	WC	A significant increase in wear resistance.
Tosun et al. [25]	TIG	AISI 1010	Ni-WC	The influence of, current scan speed of torch and thickness of powder layer on coating hardness and micro-structure was investigated.
Peng [26]	TIG	carbon steel	WC, TiN & TiC,	Wear properties enhanced.
Hodgkiess et al. [30]	HVOF	Austenitic stainless steel	Ni–Cr–Si–B–C	Erosion and corrosion characteristics improved.
De Souza and Neville [31]	D-Gun thermal Spray	UNS S32760& UNS S31603 stainless steels	WC–Co–Cr	Achieved a good wear and corrosion resistance in liquid–solid impingement.
Kumar et al. [32]	HVOF	steels SA516Grade 70 & SAE213 T22	Nanostructured Ni–20Cr	Resulted higher erosion–corrosion resistance under actual boiler conditions.
Hemmati et al. [33]	HVOF	carbon steel	Cr_3C_2-25NiCr	Results showed that cladding were large enough to postpone crack initiation and development.
Thi et al.[40]	Atmospheric pressure plasma spraying	AISI 304	Cr_3C_2-25NiCr	Resulted greater wear and corrosion resistances than sealed by conventional impregnation method and unsealed coating.
Xie et al. [41]	HVAF	AISI 316L	AlFeNiCoCr	Coating outperforms the 316L stainless steel substrate in terms of abrasion wear resistance and corrosion resistance.
Kim et al. [43]	Laser	T-800 steel	WC	Coating layer with WC proved to be more wear resistant in a wear test.
Lin et al. [45]	HVOF	Stainless-steel	WC10Co4Cr & WC10Ni	Cavitation erosion resistance in NaCl medium improved.
Qiao et al. [46]	HVOF	AISI 304	WC-Ni, WC-Cr_3C_2.Ni and WC-CoCr.	Lesser loss rates of abrasion wear of all the claddings. Furthermore, greater microhardness coatings proved to have better abrasive wear resistance.
Ribu et al. [47]	HVOF	Steel 35Cr-Mo	WC-10Co	Findings showed rotating velocity was the prime factor in affecting coating mass loss, then impingement angle, slurry composition& duration.
Huang et al. [50]	HVOF	Martensite stainless steel	WC-Co-Cr	Anti-cavitation performance improved.
Fedrizzi et al. [51]	HVOF	Steel cylinders	75Cr_3C_2–25NiCr	Coatings exhibited a lower weight loss value than hard chrome & traditional HVOF coatings during all operating conditions.
Hong et al. [53]	HVOF	AISI 1045	WC-Co-Cr, Al_2O_3	Wear characteristics much improved compared to alumina.
Pang et al. [54]	Laser	Stainless-steel	TiC-Ni/Mo/TiN	Resulted in a considerable improvement in Vickers hardness.
Singh et al. [56]	HVOF	AISI 316L	Mo_2C-based WC-CoCr cermet	Mo_2C-based WC-CoCr coating delivers superior microhardness, resistance to wear increased by approx. 10%, slurry erosion performance increased by 69.6%.
Azarmi et al. [58]	HVAF	AISI 1040	WC-20CrC-7Ni, WC-10Co4Cr	WC-20CrC-7Ni coatings improve cavitation resistance and reduce material loss.
Shi-En et al. [62]	Plasma	AISI 304	Ternary boride cermet	Resulted in strong metallurgical bond with the 304 stainless-steel matrix, with no defects such as macro fractures or holes at the interface. The cladding layer's average microhardness was 630.4 $HV_{0.5}$, approx. 3 times more than 304 stainless steel.

3. Summary and conclusion

Cermets uses a combination of ceramic and metallic phases to create materials with the greatest potential results. Cermet Coatings, which may be deposited utilising a number of sprayed thermally techniques, which provides functional alternative for resistance to corrosion and wear. Coatings of WC and CrC are frequently used to enhance resistance to sliding wear, erosive and hot corrosion as well as to lower the coefficient of friction in mating components. Despite the high technical potential of nanostructured cermet coatings, Due of the high cost of manufacturing nano powders, their usage is restricted (resistance to wear: erosion, sliding, abrasion). To fully harness the potential of such nanostructured cermet coatings, certain significant enhancements are necessary. End-users may benefit from nano-phased thermal spray cermet coatings because they can deliver new, more effective reduced friction solutions while saving money.

CRediT authorship contribution statement

Md Sarfaraz Alam: Methodology, Formal analysis, Writing – original draft. **Anil Kumar Das:** Conceptualization, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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