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Review on Various Types of Coatings on Metal and Steel Alloys

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ABSTRACT: Coatings are used in various production and manufacturing industries for the purposes viz. to increase tool life, to have better surface finish or surface quality of product. These enhancements will help industries to increase their production rate and profit margin also. Coatings are used on different metal and steel alloys to enhance their physical and mechanical properties. Rare earth elements as additive in coating had shown a significance increase in the performance of developed coating. The present paper represents and review the research work on the various types of coatings and its effects on the performance of the substrate used. This paper also discusses the studies done by various researchers on the coating developed with Rare earth elements. The results from literature exhibited an improvement in the characteristic properties of different metal, steel and tool steel alloys. The last part of this paper, presents the utilization/importance of various coatings on steels and tool steels along with future scope of research work.

Keywords: Coating, Coating on Metal and Steel alloys, Rare Earth Coating, Coating on Tool Steel.

I INTRODUCTON

Steel is an alloy of iron and carbon mixed with some other elements depending on the required properties of the resulting compound. Steel is majorly known for its high tensile strength and low cost, but one of its major applications is its use in manufacturing sector as tool steel [1].Tool steel is a high-quality alloy made from carbon and steel, specifically used for the development of reamers, cutters, bits and for machining metals, wood and plastics. These tools are widely used in every manufacturing industry. Few of the applications of tool steels are scissors, nail cutters, hammers, bridges, buildings, railways lines, automobiles etc. [2].

As the world is striding forward at lightning pace, in the field of engineering, there is an everyday need to keep the machineries developed to the most advanced level, and with them the instruments and tools that are used to make them. Since the wear and corrosion of tools have been a consistent problem in the manufacturing sector resulting in the decrease of their life span. The overcome of this problem by various methods is one of the most popular research now a days. Increase of the surface hardness and coatings on tools are few accepted solution to control this problem [3].

Coating can be simply defined as a layer of material deposited onto a surface to enhance the surface properties, especially for the corrosion and wear protection. The manner in which a substrate is coated, like the thickness of the deposited material, determines the resulting performance of the surface. Earlier, paints and grease were the most commonly used coating agents. But now researchers have found that metallic powder and oxides of rare earth elements can be used to cover surfaces, providing incredible and previously unachievable properties that can help the engineering field in numerable ways [4].

There are 17 Rare Earth Elements (REEs); 15 lanthanides (La, Ce, Pr, Nd, Pm, Sa, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) and 2 transition metals (Sc, Y). In the recent years coating with the REE have been studied by the various researchers and the results declared are in the positive direction. REEs have proven to be environmentally acceptable aqueous corrosion inhibitors and to have anti-carcinogenic properties also. Along with these, their unique individual properties have allowed the researchers to invent coating on tool steel that makes it tough and durable. For example, the Ce-based conversion coating (CeCC) had gained some popularity now because of its modest price, acceptable eco-friendliness, good corrosion resistance, and synergism and compatibility with inorganic and organic co-additives [5].

This paper will present state of art work in the field of coating and rare earth coating to improve the properties of tool steel, steels and metal alloys in particular.

II COATING ON TOOL STEEL

A.Aramcharoen et al. [6] have studied the effect of coating on the performance of H13 tool steel (45 HRC). The coating of TiCN, TiAlN, CrN & CrTiAlN was applied on the substrate utilizing physical vapour deposition (PVD). The results exhibited that these coating helped in reducing edge radius wear and cutting-edge chipping of the substrate. It was also observed that there was a reduction in flank wear with the coating of TiN and CrTiAlN, when it was compared with uncoated tools. The coating delamination on CrN & TiCN coatings was observed and the best results of least edge chipping and flank wear with good surface finish was shown by TiN coating. The results also exhibited a reduction in burr size in all these types of coatings except TiAlN coating.

Electrical discharge alloying of Ni, W, WC, & Cr on AISI-D2 die steel was done by M. Duraiselvam et al. [7]. A good bonding of nickel and tungsten element on AISI-D2 steel was observed with EDA process. Ni, W and other carbides helped in increase of average microhardness of the die steel from 275HV0.3 to 982 HV0.3 as compared to the base material. At high temperature, alloyed layer has shown higher specific wear rate with low coefficient of friction. It was observed that due to presence of chromium and carbon there was high temperature spark which resulted in various phase transformation of Ni, W, WC & Cr7C3 in the alloyed layer. E.Bemporad et al. [8] have studied the effect of TiN and TiCn coating on X82WMoV tool steel. The coating was prepared of 0.6mm thick TiCn and then followed by 4 and 6 layers of TiN-TiCn with overall 2.1mm thickness. A variation of hardness for 6 and 4 layers of TiN-TiCn was noticed, but 4 layers of TiN-TiCn had better hardness as compared to 6 layers of TiN-TiCn.

Co- based alloy coating was prepared by powder feeding laser cladding on a tool steel by Jiandong Hu et al. [9]. The author stated that about 1.0 mm surface layer can be achieved through the coating. During the microstructural investigations Cellar and then dendrite structure was formed from interface to the top surface. At the interference, the value of microhardness was increased from 588 HV0.2 to 629 HV0.2 due to the Planner solidification. Titanium nitride (TiN) coating was prepared by physical vapor deposition (PVD) on AISI D2 tool steel by Y.H. Guu et al. [10]. The results exhibited that the fatigue endurance limit can be achieved more to 10% and 29.4% in different case consideration. An increase on adhesion strength and surface hardness were also observed, but surface roughness was slightly decreasing. There was an increase in compressive residual stress and decrease in tensile stress on the surface layer.

Peter C. King et al.[11] have studied the effect of Cr (N, C) coating formation by thermo-reactive deposition & diffusion (TRD) on Pre-nitrocarburized H13 Tool Steel. It was observed that at 5700 C chromium was deposited in a fluidized bed reactor. An increase in the rate of coating formation was noticed when 30% H2 gas was introduced in it. Iron nitride as cover layer was formed and along with porosity was observed due to uncontrolled nitro carburizing. Physical vapor deposition (PVD) coatings of TiN, TiB2, TaC, Wc/c on Cold work tool steel was developed by B. Podgornik et al. [12]. The results proved that Stainless steel transfer can be withstand by coating on higher critical load by smoothening of the surface. When compared to finest substrate polishing, better galling properties can be achieved by post polishing of a coated surface and ground. The galling properties and friction were improved in forming tool with increase in adhesion between coating and substrate due to presence of carbon-based coatings.

Physical vapor deposition (PVD) coatings of TiN, TiB2, VN, TaC, DlC on Cold work tool steel was executed by B. Podgornik et al. [3]. It was concluded that in austenite steel, excellent protection against galling and low friction could be achieved by carbon-based coatings. Nitride and DLC coating showed excellent resistance against galling. At the low load values, titanium alloys regardless of coating started to adhere to tool surface. An improvement in the galling performance was observed during plasma nitriding and VN coating. Shanyog Zhang et al. [13] have studied the effect of TiN coatings on tool steels which was prepared by Physical vapor deposition (PVD) process. It was seen that that this process was more preferable over Chemical vapor deposition (CVD) process due to the various advantages. The limitation of Physical vapor deposition (PVD) during coating of complex component were rotation of workpiece, coating temperature and uniformity in coating.

After reviewing the research work available in the literature, it can be concluded that TiCN, TiAlN, CrN, CrTiAlN, TiN metallic powder is widely used for coating purpose. TiN has shown the best result in increasing the performance of tool steel. The literature has proved that the metallic coating helped in increasing the life of tool.

III RARE EARTH COATING ON STEEL AND METALS

Ramanathan et al.[14] have studied the effect of coating on Fe20Cr alloy at 1000oC. The coating was oxide of Ce, La, Pr and Y which was prepared by sol gel process. It was concluded that Ceo2, La2O3 and Pr2O3 coatings on Fe-20Cr alloy surface resulted in more uniform and adherent as compared to the Y2O3 coating. A thin alumina and chromia scales on RE oxide were observed during coating. The growth of chromia was directly proportional to the ion radius of Rare earth. It was observed that during extended period of oxidation Pr2O3, La2O3 and CeO2 were more adherent to the alloy surface. Ramanathan et al.[15] have studied the effect of coating on Fe20Cr alloy at 900° C. The coating was developed with the oxide of La, Ce, Pr, Ne, Sm, Gd, Dy, Y, Er, Yb utilizing sol gel method. It was observed that Cyclic oxidation resistance was influenced in decreasing order with the RE ion radius, resistance to thermal stress, RE oxide stability at high temperature, RE oxide morphology and stability.

Kofstad et al.[16] have studied the effect of coating on chromium and aluminum alloys. The coating was mainly focused on yttrium and other Rare earth element. It was observed that under high temperature, there was a decrease in growth rate of chromia and alumina scale. Thermal plasma spray coating of La, Zr, Ce, Y on M38G alloy was developed by Sidhu et al.[17]. At high temperature, it was observed that there was improvement in durability of coating with the decrease in thermal stress and improve in spallation resistance, fracture toughness and tolerance to crack propagation. Zain et al.[18] have studied the properties of AZ91D magnesium alloy coated with anodizing aqueous solutions containing lanthanum nitrate and magnesium nitrate. It was observed that there was formation of some closed microcracks of good quality through SEM and XRD analysis. Anodic oxidation coating had improved corrosion resistance in AZ91D magnesium alloys. The other important observation was that this coating is alternative to Cr6+ based coatings which are undesirable for environment.

Zheng et al.[19] have studied the effect of Ti(y)n coating on 18-8 stainless steel using electrochemical potentio-dynamic polarization. It was observed that there was enhancement of adhesion force of TiN coating when added with RE element. AN improvement in the wear and corrosion resistance was also noticed during investigations. Prasad et al. [20] have studied the effect of Ni/La2O3 coating on AISI 1040 steel by using microwave irradiation process. For the development of 500 µm coating thickness the process conditions of power 900W, 2.5GHz frequency for 240 sec was maintained. An improvement in the average Vickers microhardness was observed during the investigation. Tao et al.[21] have studied the effect of Ceo2 coating on stainless steel which was coated by laser coating process method. It was concluded that toughness of coating was improved and particles of tungsten carbide was rapidly dissolute. It was seen that 0.5% of Ceo2 has shown the good corrosive and wear resistance. The spheroidization of eutectic structure while formation of coating was also observed. Doping of Ce rare earth on Ni3Al alloys was performed and studied by Yuan et al.[22]. The results exhibited that fabricability of cold rolling was poor when cerium content was greater than 0.044 wt% or less than 0.083 wt%. Tensile property was also improved and cerium content plays an important role in the ductility of material. Dwivedi et al. [23] have studied the effect of CeO2 coating on carbon steel through flame sprayed coating. During the microstructural investigations the elements were uniformly distributed with the refinement of grains. Coating hardness was increased by 20%. An improvement of 21% in wear rate of coating was observed with the 0.8 wt.% cerium oxide. Basically, due to the refinement of grain and improved hardness contributed in the increase of wear resistance. Laser clad coating of La2O3 on AISI1045 Steel was done by Wang et al.[24]. It was observed that dendrite arm space was reduced. The presence of La2O3 promoted an increase of wear and corrosion resistance.

Saji et al.[5] have studied the effect of CeO2 coating on magnesium metal. It was observed that surface morphological typically have crack-mud bi/tri-layered structure with inner crystalline layer. A deposition of Ce3+ and Ce4+ phases improved the corrosion resistance of the metal. Hot dip galvanizing coating of Lanthanum (La) and cerium (Ce) on Q345 steel was developed by Han et al.[25]. The result exhibited the development of new phase such as LaAl3 and Al11Ce3. The coating composition and microstructure was refined. The corrosion resistance of the steel was also improved with the introduction of La. Harvey et al.[26] have studied the effect of cerium coating on aluminum alloys. It was observed that inadequate and inconsistent of corrosion resistance was there due to the presence of phosphate.

The literature has shown that the rare earth element oxides are widely used for coating purpose. When rare earth element oxide was used as additive in metallic powder, it has shown the best result in increasing the property for required application of steel and metal alloys. The literature has also proved that the Rare earth oxide coating helped in increasing the life considering the quality and serviceability for steel and metal alloys which are used for various applications.

IV RARE EARTH COATING ON TOOL STEELS

Microwave hybrid heating of CeO2 coating on P20 tool steel was performed and studied by Singh et al. [27]. It was observed that microstructure was refined by the addition of 1.0wt% CeO2. Hardness and wear resistance were enhanced due to the presence of hard carbides and hard phase. An improvement of 30% in hardness was recorded by the author due to the addition of CeO2. Increase in coarse grit size and sliding speed promoted the wear resistance of the P20. Sarin et al.[28] had studied the effect of yttrium oxide, Hafnium oxides, zirconium oxide and lanthanide rare earth oxides coatings on Nitride Coated silicon nitride cutting tool. It was concluded that mechanical and chemical wear resistance was increased with the addition of RE elements.

Singh et al.[4] have studied the effect of Neodymium oxide coating on P20 tool steel. The microstructure was refined with the increased percentage of neodymium. An improvement in the hardness value resulted in the lower abrasive wear of the substrate. Coating of yttrium oxide, Hafnium oxides, zirconium oxide and lanthanide rare earth oxides on Carbide Coated composite silicon nitride ceramic cutting tool was developed by Sarin et al.[29]. It was concluded that mechanical and chemical wear resistance was increased. Sarin et al.[30–32] have studied the effect of yttrium oxide, Hafnium oxides, zirconium oxide and lanthanide rare earth oxides on Alumina Coated composite silicon nitride ceramic cutting tool, carbide Coated silicon nitride cutting tool and Coated composite silicon nitride cutting tool . It was concluded that mechanical and chemical wear resistance was increased. Metal oxide densification was recommended for yttrium and hafnium oxide.

The literature has proved that the Rare earth oxide coating helped in increasing the tool life and also helped in increasing wear resistance, high temperature oxidation resistance and corrosion resistance of the tool steels.

V CONCLUSIONS AND FUTURE SCOPE OF WORK

The review paper has summarized the collective information which will be helpful to researchers in advancement of coating on steel and metal alloys. Rare earth element oxide as additive in metallic coating was found to be superior than traditional metallic coating. This type of coating has shown a positive influence both in steel and tool steel. Literature analysis has shown that the rare earth coating as additive is preferred over metallic coating. Most of the high temperature oxidation studies have suggested that introducing RECCs will provide better resistance to oxidation at high temperature. This is mainly important in tool steel which are exposed to high working temperature.

Commercialization of RECCs conversion coating could be possible by optimizing various experimental condition. RECCs coating can be explored and developed for specific application by the researchers. These RECCs coatings can be developed and studied on various types of tool steels as the coating will increase their life for various cutting parameters. Most of the research work on RECCs on tool steel was limited to cerium and lanthanum oxide. The RECCs with the other REE can be developed and studied for the various engineering and other applications.

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