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Reducing The Wear and Corrosion of The Agricultural Machinery By Electrodeposition Nanocomposite Coatings – Review

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AGRICULTURAL production is a world spearhead to face hungry crisis and the main part of this facing is agricultural machinery. Agricultural machinery exposed to failure due to wear and corrosion. This leads to a decreasing lifetime of working parts of agricultural machinery. Agricultural machinery contain seedbed preparation machinery, planting machinery, service and protection machinery, harvesting machinery and post-harvest machinery all types of agricultural machinery deals with different soil condition (soil moistures and soil types), plants (different stem diameter, cutting heights and plants moisture), and agricultural chemical (pesticides and chemical fertilizer). There are many studies searching the optimum method to increase the wear resistance of working parts of agricultural machinery. These methods contain the improvement the new material, hardfacing allying, surface coating, and nanocomposite coating. Nanocomposite coating is a new trend to promote surface properties of the different metal used in manufacturing agricultural machinery. This new trend use nanoparticles as reinforcement in the metal matrix and incorporation process lead to super hardness coating with low corrosion rate and low wear rate compared to conventional surface coating materials.

Keywords: Agricultural machinery; Cost of corrosion; Nanocomposite coatings; Electrodeposition.

1. Introduction

Agricultural mechanization plays an important role in achieving many united nation's sustainable development oals, especially the first goal (No poverty) and second goal (Zero Hungry) [1]. Agricultural mechanization can help the sustainable development of world food systems by increasing output production and reducing lost foods through the production chain [2]. Agricultural mechanization covers the manufacture, use, maintenance, and repair of machines using in agricultural production (crop and livestock), in addition to, post-harvest process [3]. Agricultural machinery is working in special and hard conditions. Where it deals with different kinds from the environment, soil, plants, pesticide, fertilizers, and post-harvest processing due to reaction between agriculture machines and this condition lead to exposing for wear such as adhesive, abrasive, fatigue, erosion, chemical, and corrosion [4,5]. In addition, figure 1 explains effect different condition in agricultural machinery wear.

The aim of this work is reviewing the wear and corrosion effect on agricultral machinery and reviewing effect of nanocomposite coating for reducing corrosion and wear in agricultural machinery sector for increasing lifetime service of agricultral engineering.

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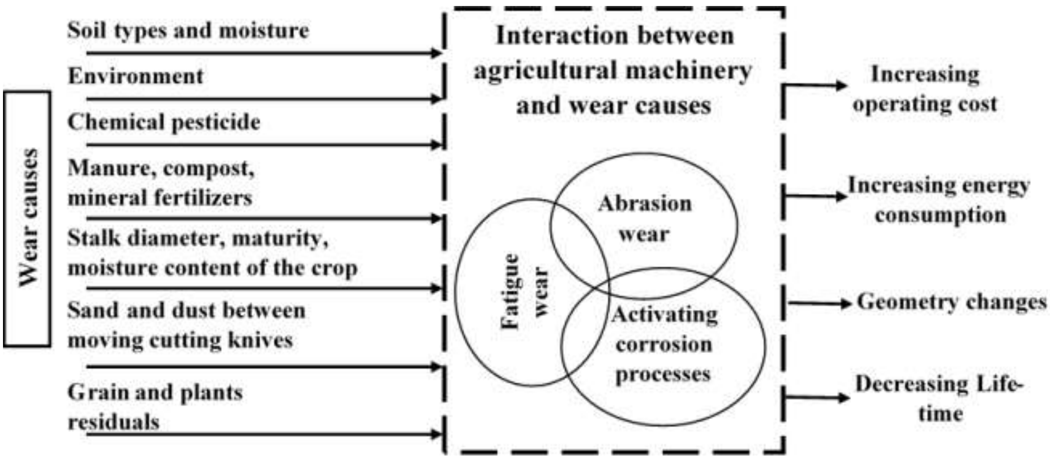


Fig.1. Wear in agriculture machinery.

2. Wear and corrosion phenomena in agricultural machinery

2.1. Wear phenomena in agricultural machinery

Wear is cumulative damage due to the action of relative motion with solid surface substance. International American Society (IAS) for testing and materials defines wear as losing material due to the opposite moving between different bodies [6]. All machines and the mechanical system have moving parts from different material, so that wear is the biggest problem in the industry [7].

Hutchings et al.[8] remind that in the wear and friction process, there are relationships between different material properties (physical, mechanical, and chemical) andstructurel of the moving surfaces. Although wear can occur by mechanical and chemical and it is generally accelerated by thermal means. There are many principles for wear including abrasion, fatigue, adhesive, impact, chemical, and wear by electrical arc induced [9]. Figure 2 shows the different types of wear.problems or produce speedy significant advances in technological progress.

2.2. Corrosion in agricultural machinery

Hou in 2019 has been pinpointed that the cost of corrosion in the world is about 2.505 billion dollars and this represents 3.4 % of the gross national product (GNP) as shown in (Table1). In addition, the effective control of corrosion through modified coatings, new materials, and preventative maintenance is estimated to reduce this cost by 15–35% or as much as 875 billion dollars annually [11,12]. The cost of wear and friction in turkey is decreased by 337 million dollars due to improve the material used in the industry against corrosion and wear [13,14].

There are about 1.9 million farms in the USA produce livestock and crops. All these farms have big problems with the cost of replacing machinery and equipment due to wear and corrosion. The cost of these problems in the agriculture sector was estimated to be 1.1 billion dollars [15]. In addition, in China, the cost of corrosion in the agriculture machine sector was 1.38 billion dollars as 2.5 % of the total estimate value of the agricultural machinery industry [16]. Moreover, the number of agricultural machinery in Egypt is increasing in recent years due to the interesting Egyptian government to increase agriculture production, for example harvesters machines increase from 1995 to 2015 (1190 unit to 5371unit) respectively and the tractor numbers in 1995 was 89090 tractor and become 133298 tractor in 2015 [17].

Agricultural machinery refers to the machines used in plant production and husbandry production as seedbed preparation machines, plating and production machines, harvesting machines, processing machines, Livestock machinery, and agricultural transport machinery. At present, there are about 3,500 kinds of agricultural machinery products in China [18]. Repair and maintenance are necessary for keeping a machine parts with minimized effect corrosion, part failures, accidents, and natural deterioration. Moreover, the repairing costs for a machine are highly variable and good management may keep costs low [19].

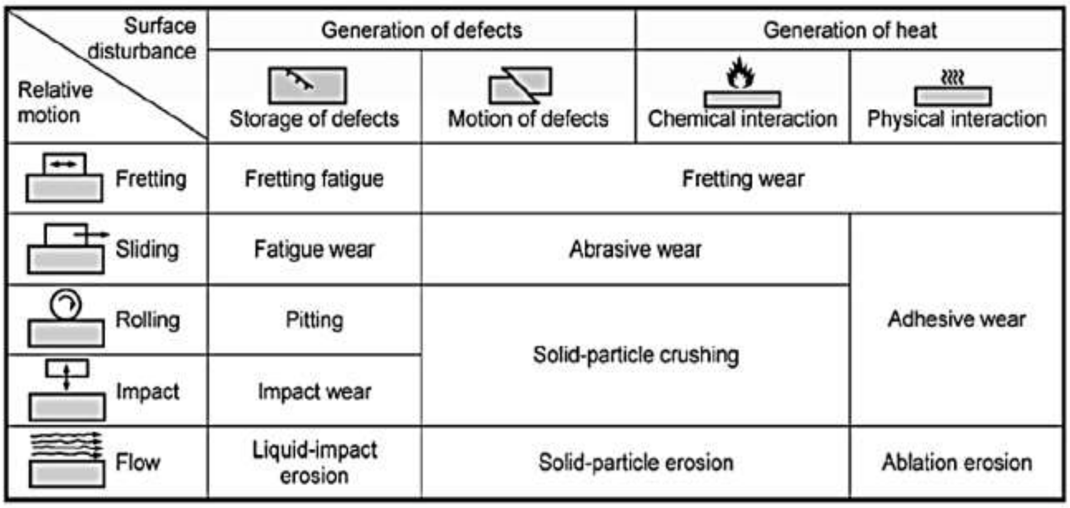


Fig.2. The different types of wear and their

Table 1. Cost of Corrosion in different sector in different

Economic Regions	The cost of corrosion		
	Corrosion Cost of Agriculture	**Corrosion Cost of industry**	**Total cost of corrosion**
USA	2.0 billion USD. [11] 1.1 billion USD. [15]	303.2 billion USD.[11]	451.3 billion USD [11]
China	1.348 billion USD (RMB 9.89 billion) [16]	192.5 billion USD.[11]	305 billion USD (RMB 2,178.82 billion) [16]
Global	152.7 billion USD [11]	1446.7 billion USD.[11]	2505.4 billion USD [11]

Wear in agriculture working parts leads to an increase in fuel consumption and decreasing the lifetime of these parts [20]. The lifetime of agricultural machinery affected by wear and the lifetime of harvester machine is 2000 hours after working time [21].

2.3. Seedbed preparation machine

The seedbed preparation machines have been interacting with soil in different conditions as textures, moistures and other unpredictable conditions in the field. This interaction produces abrasion wear. Abrasion wear in seedbed preparation machines has damage 40% of components of machines [22,23]. Natsis et al. 2008 [22] determined the relationships between share edges wear width and soil moisture in different types of soil. Table 2 listed the defects on the surface of share plough after the ploughing process and this defecting point was observed by scanning electronic microscope (SEM). Figure 3 shows the subsoil plow knife with rough surface topography due to plowing caused by the abrasive particles. The grooves are wide, deep, and randomly orientated as see in Fig. 5a. There are imprints grooves due to sand abrasive particles as is shown in Fig. 5 a and b. Moreover, there are many pitting and spalling observing at the surfaces, which originate from the removal of larger areas of material (Fig. 5c.) [5].

2.4. Sowing and planting machines

Sowing and planting machines exposed to failure in many components, the first failure represented in the transmission mechanism, the agitator, and the feed roller. Although, this failure appearance in breaks on the ruptures and bearing and cracking and ruptures wear type and this cracking wear in planting machines resulted from a variable rate of seeds, dynamically loads in the colter shaft, lifting brackets device and trailing colter arm [25]. Another wear occurs in the opener knife of the machine due to connected with soil and the relation between opener knife and soil change the dimension of opener knife, also this problem happens with disk opener (single and double disk) and main wear in leading-edge [26,27].

Table 2. The defect which showed in the plough share

Measurement Place	Condition A (Fine sandy loam + Stone + humidity 15 % + Speed 2.76 m/s)	Condition B (Sandy loam/loam + humidity 18 % + Speed 2.04 m/s)
At the point of share	-Parallel scratches. -Parallel grooves.	-Fine and short scratches proving impact action of abrasive particles. -Grooves with plastically deformed material at their edge. -Fine pinholes.
At the wing of share	-Parallel scratches. -Parallel grooves. -Fine pinholes.	-Fine and short scratches proving impact action of abrasive particles. -Deep and parallel scratches caused by larger abrasive particles. -Fine pinholes.
At the moldboard surface	-Parallel scratches. -Parallel grooves. -Pinholes with abrasive particles.	-Scratches with plastically deformed material on their front faces. -Fine pinholes with trapped abrasive particles.

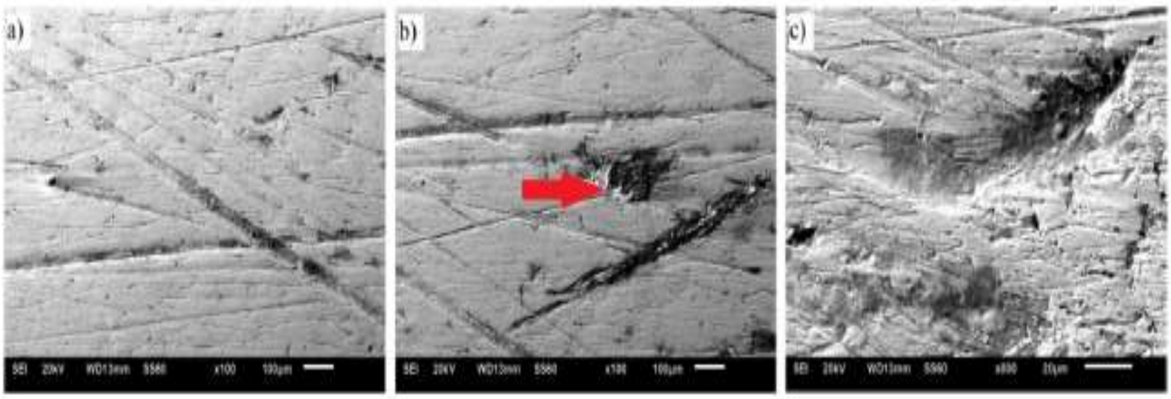


Fig. 3. Wear action due to abrasion in the subsoil plough knife surface were a) scratch paths b) impact effect c) plastic action deformation [5].

2.5. Crop Protection machines

Many studies stated that crop protection machines corrosion is caused by the effect of chemical pesticides and fertilizer used in farming. The metal elements of crop protection machines exposed to the corrosive effects of pesticides due to the direct connection between steel, brass, copper, and aluminum to pesticides [28–31]. The sprayer content especially the pump exposed to wear and corrosion due to corrosive and abrasive material used in crop production [32].

Moreover, some studies indicated that when water mixed with the pesticide in many stations from manufacturing, packaging, transportation, and usage increases the corrosion of metal surfaces of sprayers and it is a component and maintenance cost of machines is increasing [28,31].

2.6. Harvesting machine

Crop harvesting machines are strongly affected by technology and the cost of this machine represents 32.5 % cost of production [33,34]. Crop harvesting is a cutting process that causes mechanical failure of plant stems and /or leaves and thus the structure and strength of plant materials [35]. The mechanical and physical properties of the plant stem is an important parameter in the cutting process and this parameter can contain stem diameter, moisture content and shear resistance, although the strength of the plant material from a cutting point depend on strength in compression, tension, bending, shear, density, friction, and adhesion. Moreover, resistant plants to cut can elicit from the cutting energy [36,37].

There are many theories for cutting plant material, the first theory is a knife used to sever plant material. Often severing were accomplished by shearing the material between a moving knife and a stationary counter shear, another theory to cut plant material is impact cutting, and it is used in flail mowers and rotary mowers [35,38].

The cutting process is very complex because the stalks have varying textures of nonhomogeneous materials with different properties in space and time and cutting process is an intensive cutting process to beat the plant material's resistance due that the blades exposed to wear [39,40].

Calcante et al. [41], estimated the cost of maintenance of combine for grain and corn harvesting and maintenance cost of the head unit was 20.8% of the cost of maintenance due to contact with plants as is represented in (Fig.4). In another study,[42] find that the mean repair and maintenance cost distribution of combine harvester during the off-season was 3.92 times higher than the on-season and most failures in header unit, threshing unit, and transportation unit.

1.1.1.Reciprocating Cutter Bar

The reciprocating knives are being used to harvest many plants. The single knife consists of a fixed part (bar with guards and fingers) and the second part is moving part (the cutter blade) as is shown in (Fig.5). Cutting is being done by two elements moving opposite action in double type the two elements are double knife, in single type two elements are knife, and fixed finger [43]. [44] mentions that there are many types from the knife used in reciprocating mower as the long blade with smooth edges, the long blade with serrated edges, the short blade with smooth edges and the short blade with serrated edges. Figure 6 shows the serrated edge and smooth edge knife.

The cutting process by a single knife is being affected by knife speed (as sliding speed from 0.45~2.5 m/s) and the sharpness degree of cutting edge. When the edge of the knife wears from 0.1 mm (sharp edge) and becomes 0.3 mm radius (dull) cutting energy increasing approximately doubles and this wearing due to contact with plants, grain, and soil [35].

Knife wear is a combination of impact wear and abrasive wear. These are the major cause of knife destruction and limitation of cutting blade life. In heavy working environments, sufficient protection against abrasion cannot be ensured only by heat treatment, which leads to frequent replacement of the blades during work [40,45,46].

1.2. Solution for reducing wear and corrosion in agricultural machinery

There are many ways to reduce the wear and the corrosion and increase the lifetime of the machine such as the selection of the material, adapting the environment conditions, and surface treatment. Most of the agricultural machinery needs to surface engineering (coating process) that resists wear conditions and corrosion conditions at all their applications. The surface engineering includes thermal spraying, hardfacing, heat treatment, electroless, and electrodeposition coatings [31,47–49].

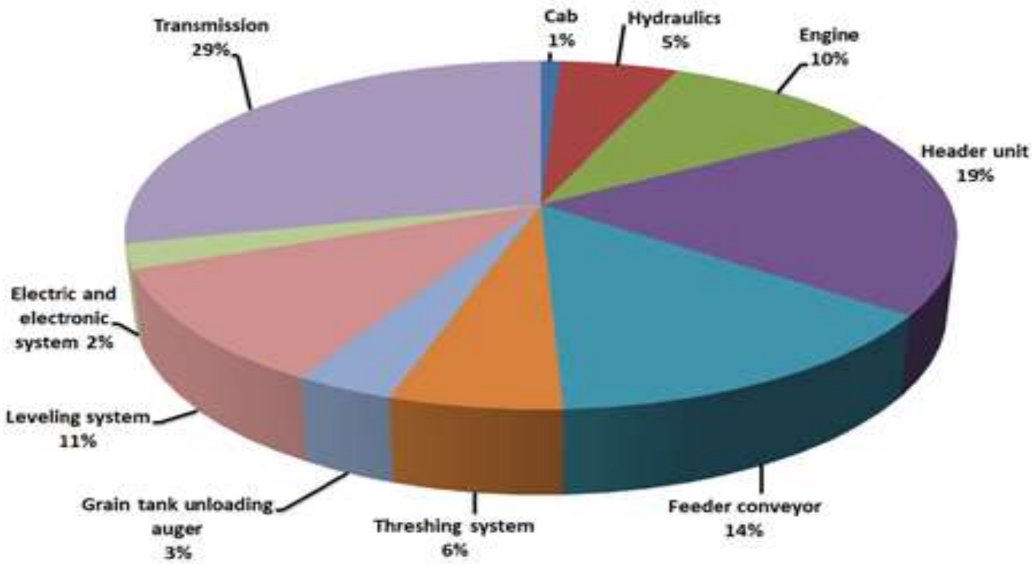


Fig . 4. The combine units maintenance cost [41].

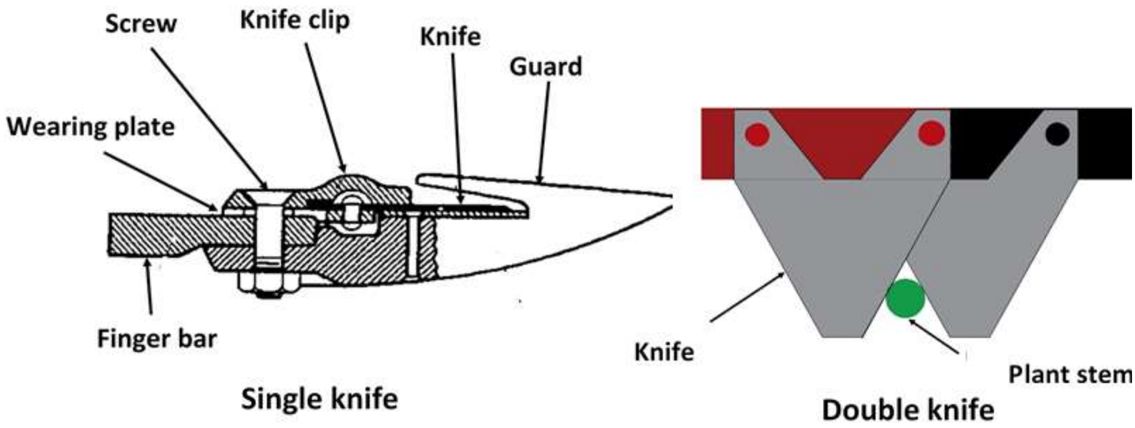


Fig. 5. The cutter blade component.

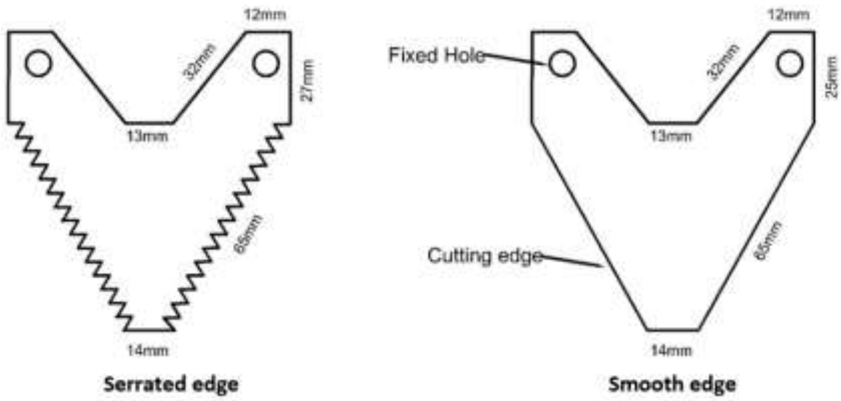


Fig. 6. Different types of mower knife.

1.3. Selection of the material

New materials against corrosion are important to improving the agricultural machinery sector [28]. Ryabov et al. [47], mention that high-strength new carbon steels had been used for soil processing agricultural machines. This steel has a yield strength of 1200, 1500, and 1700 MPa with different a carbon content of 0.30–0.45%, economically alloyed with manganese, nickel, chromium, copper, and molybdenum (in total from ~2 to ~4%) in combination with a set of micro alloying strong carbide-forming elements (titanium, niobium, vanadium), and boron.

1.4. Hardfacing technique

Hardfacing technique is a welding process used to deposit hard alloy to repairing, protective, and increasing lifetime of working parts. Hardfacing coating layer is a strong bond with substrate metal and this technique provides protection against corrosion with a maximum thickness of 10 mm [50–52]

Hardfacing technique was used for enhancing excavator bucket teeth, tillage machines and mining tools against abrasive wear. Hardfacing layer thickness ranges from 2 mm to 3 mm with many passes [53]**.** [54] applied hard alloy coatings on the working parts of agricultural machinery as hard surface against soil abrasion wear against working parts and these coating layers reduced the wear rate and mention that this method is very effective for agricultural machinery.

Kostencki et al. [55], enhancing the abrasion wear resistance of cultivator knife by hardfacing layers from pad-welded material and this technique was increased the resistance against abrasive wear and reduction width and weight knife losing. Although Horvat et al. [56], improve the moldboard plow share surface against wear with hardfaced layers by combining between two welding processes arc welding and induction welding.

1.5. Surface coatings

In general, the coating of material has an extra cost, but it is considered to be more functional, in the long-term applications, because it supplies large savings in the maintenance cost. Surface coating is a branch of surface engineering science and it is one effective solution for tribological problems. Moreover, surface coating methods are applicable to decrease the friction coefficient, change the surface roughness, increase the surface hardness, and induce residual compressive stresses. So, they extend the lifetime and improve the corrosion and wear resistance. The coating methods can be categorized into several types as the gaseous state, solution state, and molten state of deposition techniques [57]. Malvajerdi and Ghanaatshoar [58]**,** enhancing tillage duck blades against the wear through the tillage process by using gaseous physical vapor deposition (PVD) method to deposit Titanium-nitride (TiN) with thickness 4μm. Figure 7 depicts the types of coating deposition.

2.3.1 Electrodeposition of metal coatings

The electrochemical deposition technique is attractive due to the low energy consumed for depositing a coating on the different substrates. This technique has many advantages like low cost, ease of operation, versatility and high yield. Important properties for electrodeposits include wear resistance, hardness, ductility, coating layer adhesion to substrate and corrosion resistance. All these properties and characteristics can be affected by the many numbers of variables such as temperature, species concentration, electrolyte pH, current density, electrolyte flow conditions, and the use of electrolyte additives (Wills and Walsh 2006). There are many studies about increasing abrasion wear resistance for agricultural machinery working parts by using nickel and hard chromium electroplating [60,61]**.**

2.3.2 Electrodeposition of composite coatings

The composite coating is becoming a trend in the surface coating due to improving mechanical properties, abrasion resistant, corrosion resistance, reducing friction between moving parts, malleability, and increasing surface hardness. In addition, recent years were new trends by using nanoparticles as the incorporation particles into metal coating [62–65].

Nanocomposite coating technique is a new surface coating deposition process with physical and mechanical unique properties due to mixing two or more materials in the nanoscale [66]. Nanoparticles incorporation in the metal matrix can increase hardness, increasing corrosion resistance, modified growth coating to deposit nanoparticles, and shift in the reduction system of metal ion [14].

The nanometer-scale refers to the length unit as one billionth of one meter or 10^{-9}m as shown in (Fig.8). The nano prefix derived from the Greek [67]. Nanomaterial terminology refers to materials with external or internal structure in nanoscale and reducing the size of the material to nano-size leads to different physical and mechanical properties [68].

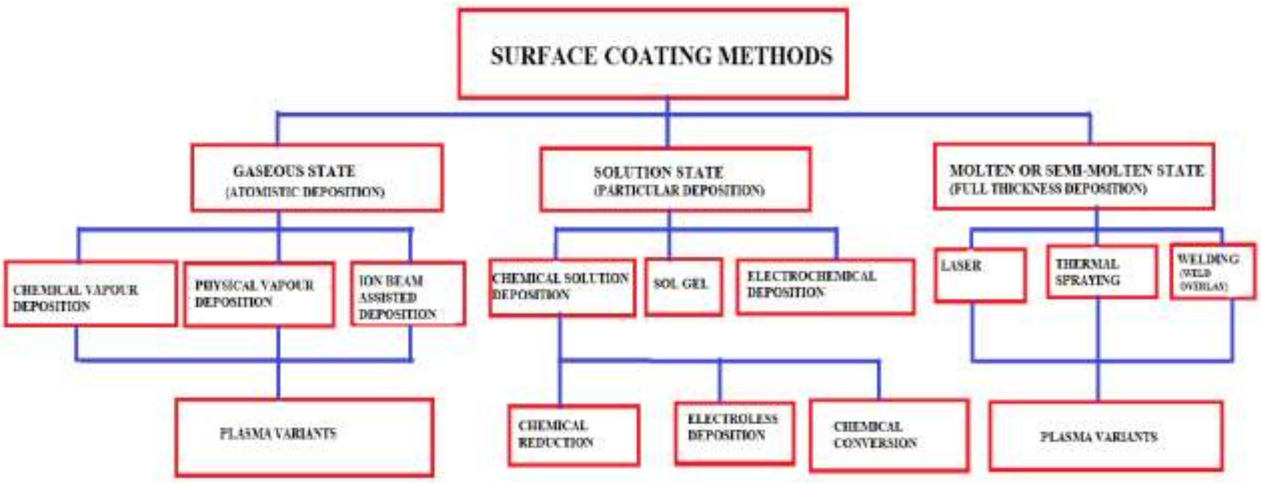


Fig. 7. A general classification of the surface coating method [59].

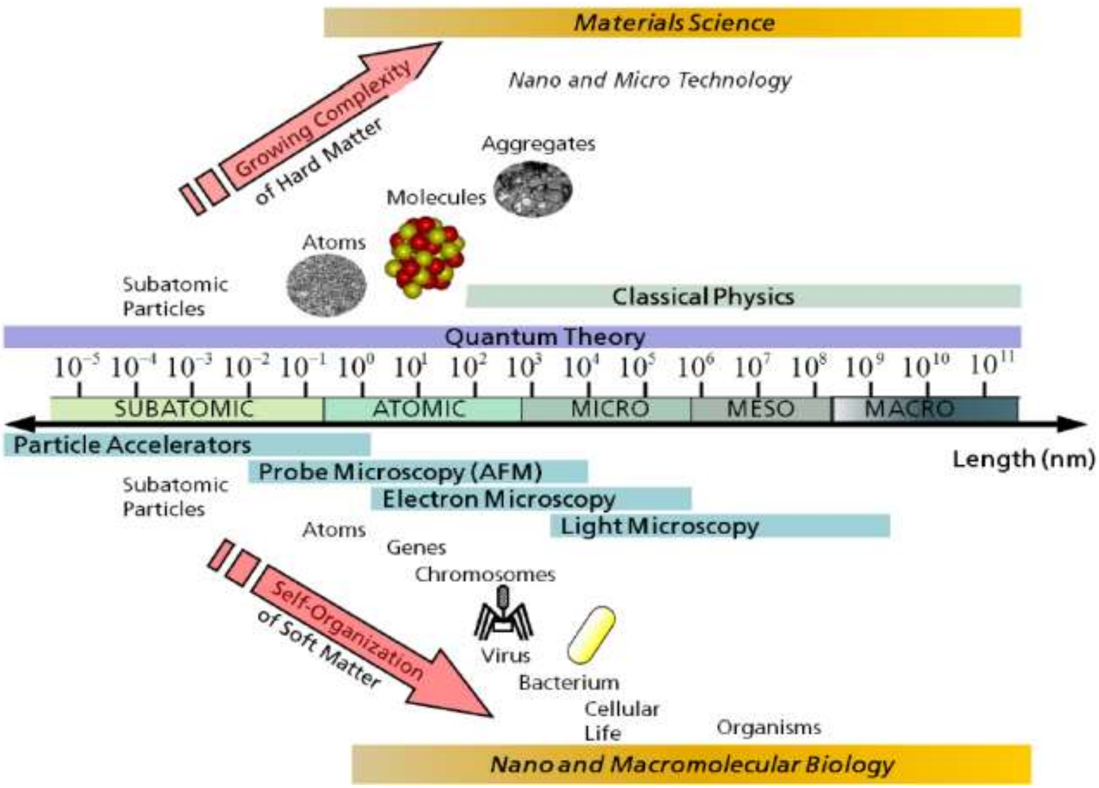


Fig.8. The scale of length and example of biological and physical systems in nanometers [69].

Nickel as metal-based for composite coating is appropriate for wear resistance in industrial systems, gear systems, measuring tools, and abrasive tools [70,71]. Figure 9 shows the effect of the size of the different particles from the micro size and nano-size in nickel composite on the hardness of the coating layers.

The particle incorporation process in the coating during electrodeposition may be divided into the transferring process of particles to the metal surface, the interaction process between particles and electrode surface and the final process is growing metal matrix (Fig.10) [73].

On the other hand, Lelevic and Walsh [75], explained the mechanism of the incorporation nanoparticles in the metal matrix during electrodeposition as several stages, first, synthesizing ionic cloud around nanoparticles in electrodeposition electrolyte, transfer nanoparticles to the cathode, nanoparticles diffusion in a hydrodynamic layer around the cathode and final process is the incorporation of nanoparticles into metal layer deposit (Fig.11).

Nanomaterials can be classified in several geometric including nanowire, nanotubes, nanorods, nanohorns, nanoshells, nanoparticles, etc. Moreover, all those materials used in advanced applications due to new properties for materials at the nanoscale [76]. The physical of nanomaterial different from the same material in a single atom or with bulk material at the same chemical composition and this phenomenon needs more study [77].

Zhang et al. [78], decide that the hardness of nanomaterial harder than the material in the amorphous phase and conventional grain size according to the relationship of 'Hall-petch' (Fig. 12). Badisch and Roy 2013, divided the nanoparticles used for reinforcement in the metal matrix as carbides (WC, TiC, ZrC, etc.), nitrides (AlN, Bn, CrN, TiN, ZrN, etc.), borides (WB, TiB_2, CrB_2, VB_2, ZrB_2, etc.), silicides (CrS_2, TiS_2, ZrS_2, etc.) or oxides (Al_2O_3, TiO_2, Y_2O_3, ZrO_2, etc.).

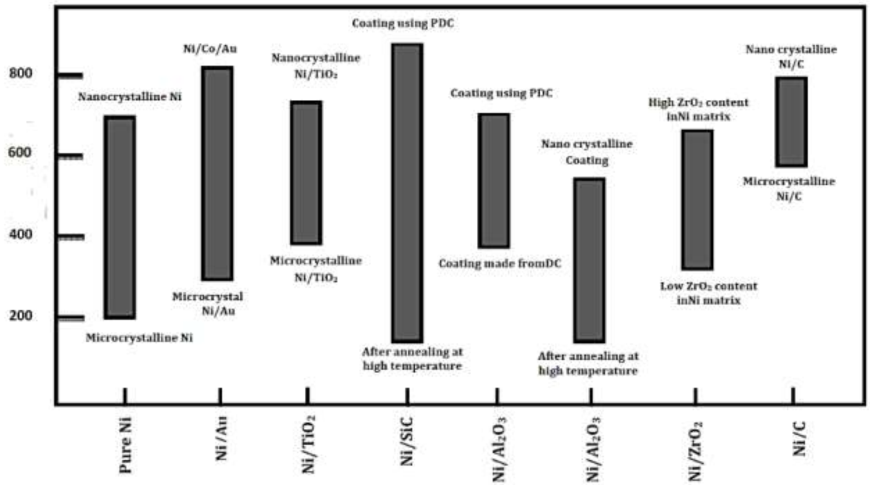


Fig. 9. Hardness of nickel composite coating with different ranged particles [72]

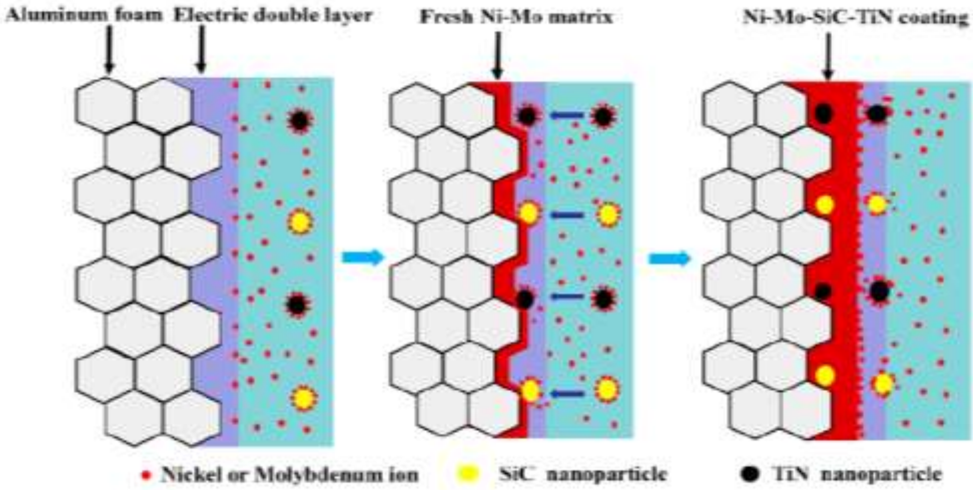
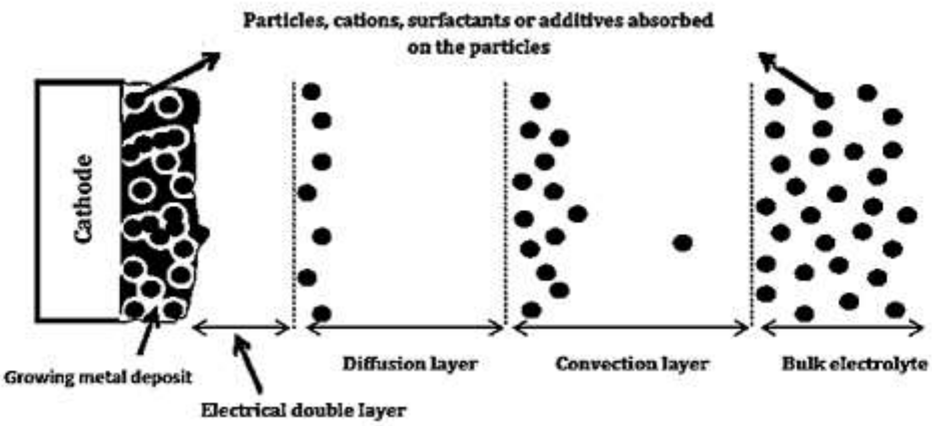


Fig.10. Nanoparticles incorporation in metal matrix mechanics [74].



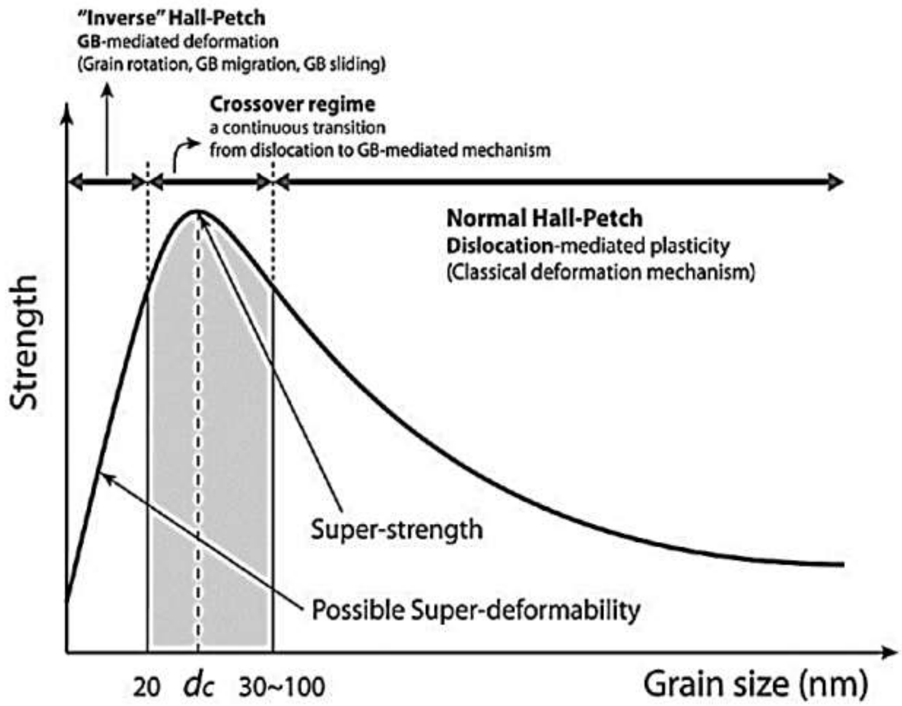


Fig. 12. The Strength of a material as a function of the grain size [79].

In the scope of the metal matrix in the composite materials, the most metals that have been used are Ni, Mg, Ti, Fe, Co, and Al. Nickel-based alloys are widely used in many broad applications such as oil field, food productivity enhancement, and some corrosive environments (water, alkali, organic and mineral acids) due to favorable properties. These excellent properties make it appropriate for the first choice of some important components in the offensive environments.

There are many types of electrodepositing baths commonly used for electrodeposition of nickel as Watt's bath, chloride baths, citrate bath, and sulphamate bath. Nickel electrodeposition from a Watt's bath has been used in many functional applications to modify or improve the corrosion resistance and increase wear resistance to increase the lifetime of service parts and reducing worm parts [80]. The physical and mechanical properties of nickel deposited from a Watt's bath are affected by the electrodeposition parameters, such as deposition time, current density, pH, cathode material, electrolyte agitation, and electrolyte temperature, and among others [81].

2.3.3 Effect of Nanocomposite coating on the corrosion resistance

The literature illustrates various techniques to produce different composite and nanocomposite coatings. Composite or nanocomposite coatings with anti-corrosive behaviors elevate changes in the metal surfaces and producing new materials with enhanced characteristics compared to those prepared by the conventional process. The number of works in the literature concluded that the production of metal composite coatings with anti-corrosive properties are depended directly on the operating conditions. Moreover, the coatings must also be investigated (chemically, morphologically, and structurally) to make a relationship between the results obtained with these analyses and the anti-corrosive behavior of the coating.

The anti-corrosive properties of the coatings are usually estimated using many processes as a salt spray or the electrochemical techniques (polarization curves, linear polarization resistance (LPR), and electrochemical impedance spectroscopy (EIS)). The rapprochement between the anti-corrosive property of pure metal and its composite coatings has been studied for several systems in different corrosive environments [82].

Ni is the most metallic coating that used to form coatings characterized by high corrosion resistance through incorporating reinforcement with the matrix to produce composite layers. For example, Szczygieł et.al [83] proved that, the corrosion resistance of Ni-Al2O3 nanocomposite coatings compared to a pure Ni coating deposited onto the steel substrate. They have been estimated the corrosion test in 0.5 molL-1 Na2SO4 solution and found that the corrosion resistance of Ni-Al2O3 composite coatings was higher than the pure Ni coating.

Kasturibai, et al [84] found the corrosion rate of coating layer Ni-SiO_2 nanocomposite coatings on the Cu substrate (0.037 mm / year) was low compared to the pure nickel coating (1.95 mm/year). Moreover, the Tafel polarization curves for Cu substrate and Cu coated by Ni-P-TiO_2 nanocomposite. The curve has a positive shift for corrosion potential (E_{corr}) for nanocomposite coating (-0.26 V) than that of the Cu substrate (-0.324 V), and the corrosion resistance is about 15 times higher than the Cu substrate [85]. Figure 13 shows the effect of Cr_2O_3 concentration in improvement Polarization curves and the corrosion resistance with increasing concentration and the optimum concentration 10 g/L.

The corrosion behavior of steel coated by pure Ni and Ni/CeO_2, nanocomposite coatings produced by square-wave pulse current mode was evaluated in a 3.5 g L-1NaCl solution. Higher Rp values were observed for the Ni-CeO_2 nanocomposite coatings (9.772×10^3 Ω) compared to the pure Ni coating (2.05×10^3 Ω). This result may be due to the presence of the ceramic particles in the matrix which act as a physical barrier layer, which assisted the anodic polarization and inhibited the pitting corrosion and rise in the uniform corrosion of the coating[87].

Measured the anodic polarization curves for nickel and Ni–SiC nanocomposite coating in 0.5M NaCl solutions have been measured by Vaezi et al. [88]. Both of them show an active-passive transition by anodic polarization, but the Ni–SiC nanocomposite coating is more positive the corrosion potential, a wide and long passive region than that of nickel coating. And in another study the Al_2O_3 nanoparticles improved the polarization curve of pure Ni as shown in (Fig. 14).

Moreover, Khalil M.W. et al. [90], had been deposited nano-composites of Ni/GNS-TiO2 coating using an electrodeposition route on the mild steel surface which used in the building of the steel silos. In addition, the corrosion behavior was estimated at in different media (Citric acid and acetic acid), they were found that the lowest corrosion rate was for the Ni-0.4g/LGNS-TiO_2/mild steel in NaCl solution samples (Fig. 15)[91].

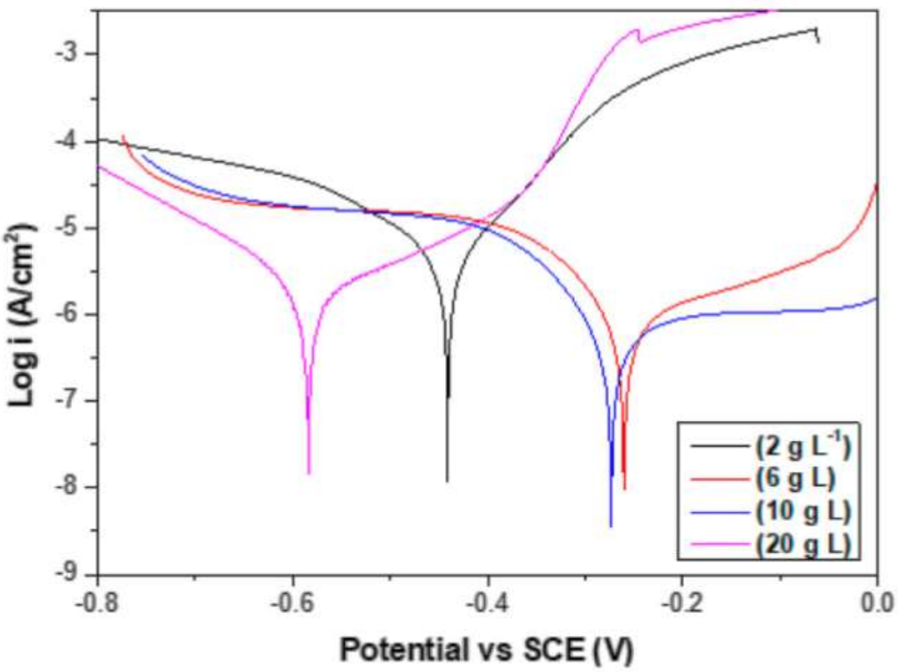


Fig. 13. The effect of Cr_2O_3 concentration in Polarization curves [86]

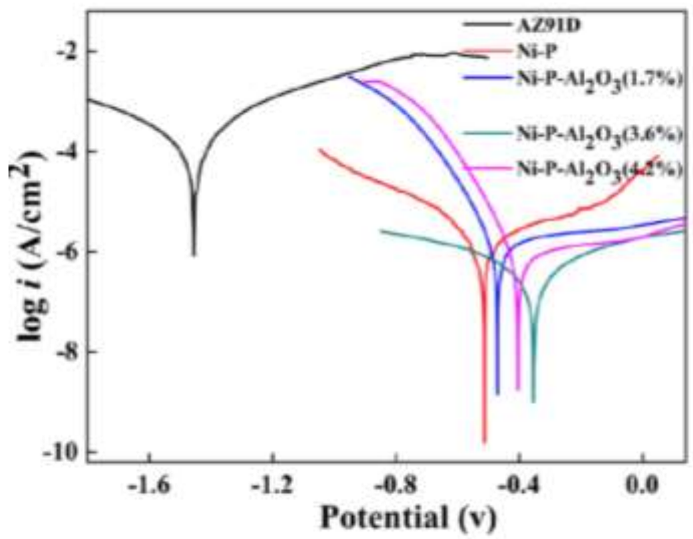
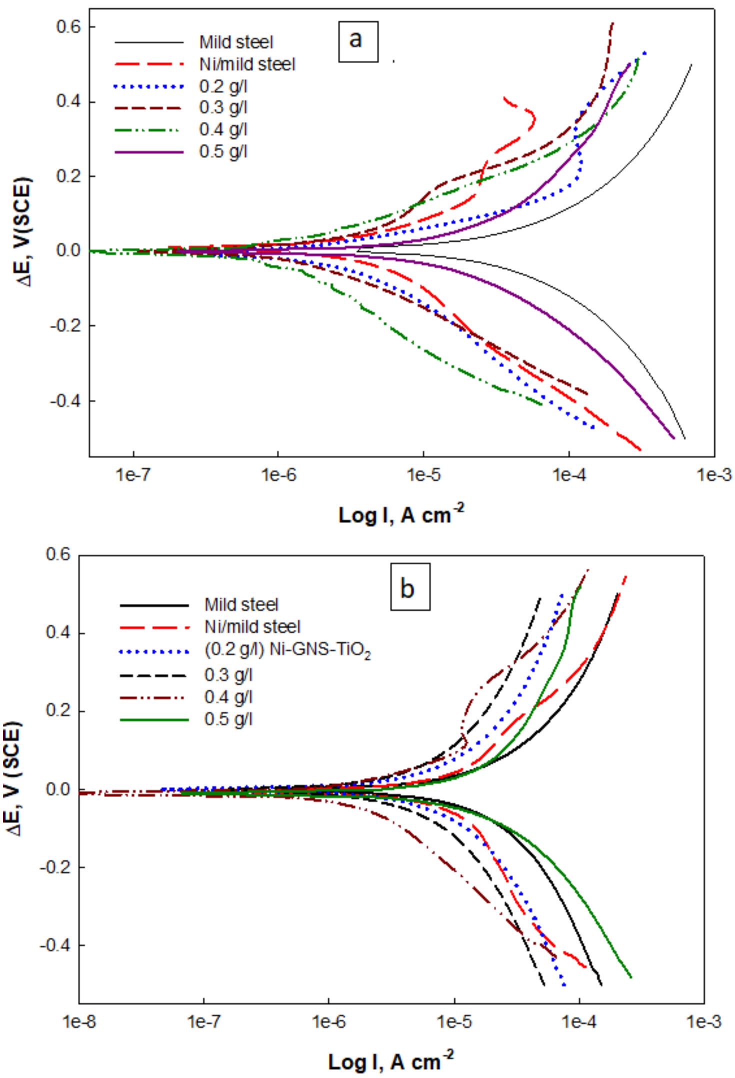


Fig. 14. polarization curves of nickel and Ni–SiC Nano-composite coating [89]**.**



. **Fig. 15. Polarization Tafel lines of mild steel, Ni/mild steel and Ni-GNS-TiO_2/mild steel in a) 0.06 M citric acid, and b) 0.1 M acetic acid solution** [91]**.**

2.3.4 Effect Nanocomposite coating in Wear resistance

Nanocomposite coatings produced coating layers having more favorable properties especially wear property compared to conventional composite, pure metallic, or alloy coatings because of the high properties of the reinforcement nanoparticles [96–98].

Vaezi et al. [88], Studied the wear rate of the nanocomposite coating with incorporation Al_2O_3 nanoparticle in metal matrix coating and the wear rate of nanocomposite coating was less than pure nickel and substrate copper.

Figure 16 shows the results of wear test of the Ni–Al2O3–SiC nanocomposite coating with clearly observable reducing the wear rate for nanocomposite coating [99]

Samuel Mbugua Nyambura et. al [86] Proved that Ni–W/Cr_2O_3 nanocomposites exhibits superior .wear resistance properties compared to Ni–W binary alloy coatings. They found the coefficient of friction patterns of the Ni–W alloy coating was about 0.6 while the friction coefficient of Ni–W/Cr_2O_3 nanocomposite coatings was about 0.48, this improvement due to better co-deposition of Cr_2O_3 nanocomposites into the matrix (as displays in Fig.17).

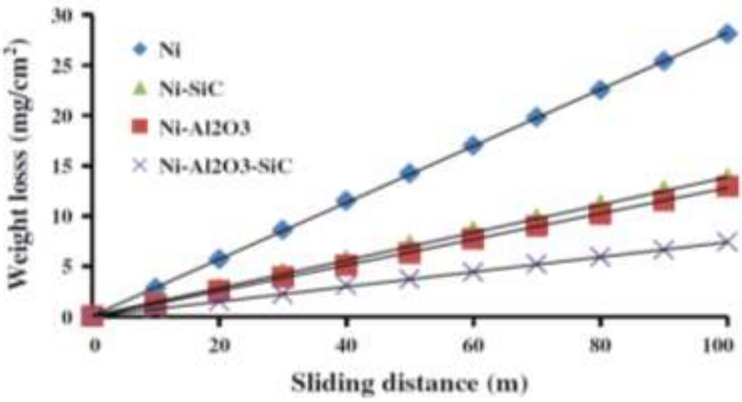


Fig. 16. The effect of Al_2O_3 and SiCnanoparticles in wear rate [99]

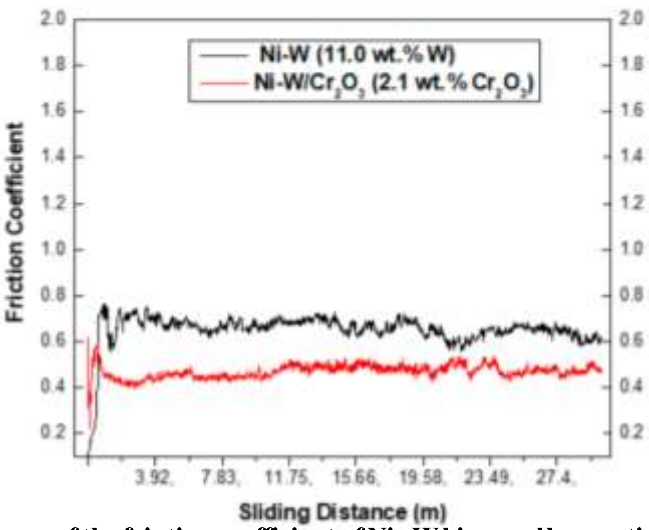


Fig. 17 Typical curve of the friction coefficient of Ni–W binary alloy coatings (11.0 wt.%), and Ni–W/Cr_2O_3 (2.1 wt.% Cr_2O_3) nanocomposite coatings[86] **.**

2.3.4 *Effect Nanocomposite coating in Hardiness*

There are many paper studies effects of nanocomposite coating in the development hardness of surfaces. Gül et al. [100] was evaluated the microhardness of unreinforced Ni and Ni–Al2O3 composite coatings and found the microhardness of the coating increases with increasing dispersed nano-particle content and microhardness of pure nickel was (280 HV.) compared with Ni–Al_2O_3 composite coatings (641 HV.). The incorporation of SiC nano-particulates in a nano-crystalline nickel matrix has also resulted in an increase in hardness from 260 to 450 VH [88]. Zhou et al. [101] study the effect of Ni-SiC nanocomposite coating in hardness and found that increase in hardness of nanocomposite coating (626 HV) compared to pure nickel (414 HV) and the substrate.

Figure 18 illustrates the effect of current density in hardness value of Ni–Fe/AlN nanocomposite coatings and the highest value with 4A/dm^2 [102]. The effect of added the carbon nanotube in improving the hardness of the coating and the hardness of nanocomposite coating was improved due to incorporation CNT with modification process [103]. Figure 19 the effect of adding Al_2O_3 in improvement the nanocomposite coating with different concentration [104].Moreover, in another study, the effect of incorporation of TiO_2 with a different concentration in nickel metal matrix in hardness was studied and the result showed that Ni-TiO_2 was increasing the hardness compared to pure nickel (Baghery et al. 2010).

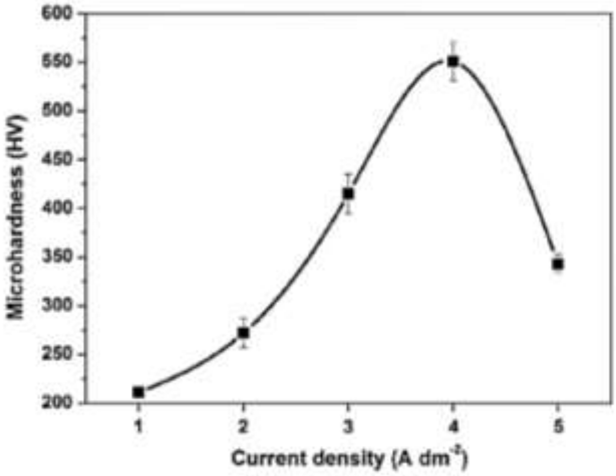


Fig. 18. The effect of current density in microhardness of Ni–Fe/AlN nanocomposite coatings [102].

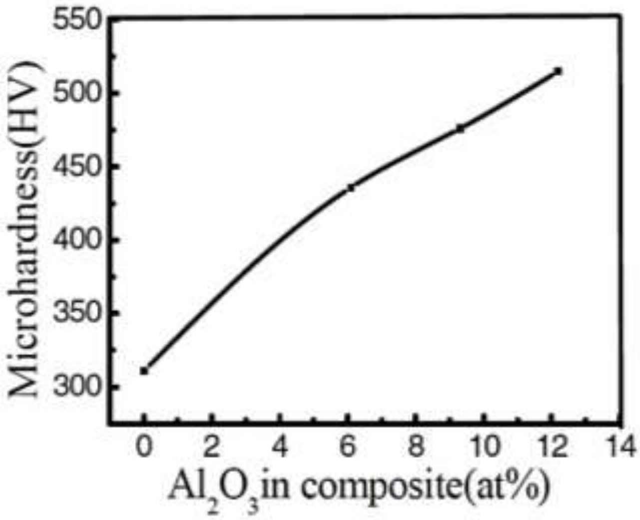


Fig. 19. The effect of concentration of Al_2O_3 particles on microhardness.

Table 3 shows a summary of the effect Nickel composite and Nickel nanocomposite on improving chemical and mechanical properties of steel. From this table, an improvement of mechanical and chemical properties of surfaces is evident due to adding the micro and nano element to the nickel coating

Conclusions

Protecting agricultural machinery from corrosion and wear operations is an important consideration to reduce agricultural production costs and increase the quality of agricultural crops. For that the nanocomposite coatings a new hope for this industry.

The corrosion performance of the composite and

Table 3. Effect Ni-composite and nanocomposite coating on improving the steel surface

	Corr. rate	Wear rate	Hardness
Uncoated mild steel **Uncoated low carbon steel**	0.181 mm/y [90] 0.310 mm/y [105]	0.018 mm^3/N-m [106] 0.038 mm^3/N-m [107]	180 HV [90] 166 HV [105]
Steel coated with pure Ni	0.049 mm/y [90] $0.110*10^{-3}$ mpy [108]	13.5×10^{-4} mm^3/N-m [70] 1.2 mg/h [109] 5.596×10^{-5} mm^3/m [110]	243 HV [90] 245 HV [111] 280 HV [109]
		Composite coating	
Steel coated with Ni-Cu	0.170 mm/y [112]	$15.18*10^{-4}$ mm^3/N-m [111]	331 HV [111]
Steel coated with Ni-Cr	0.27186 mm/y [86]	0.9 mg/h [109]	385 HV [109]
Steel coated with Ni–Zn	0.144 mm/y [113]	$6.83*10^{-3}$ mm^3/N-m [114]	253 HV [115]
Steel coated with Ni–W	-----	------	506 HV [94]
		Nanocomposite coating	
Steel coated with Ni–W/Cr_2O_3	0.00670 mm/y [86]	-----	498 HV [86]
Steel coated with Ni–GNS	0.0180mm/y [90]	------	250 HV [90]
steel coated with Ni–GNS–TiO_2	0.0004mm/y [90]	------	478 HV [90]
Steel coated with Ni–TiO_2	$0.051*10^{-3}$ mpy [108]	2.99×10^{-5} mm^3/m [110]	480 HV [108]
Steel coated with Ni- SiO_2	0.03784 mm/y [84]	------	------
Steel coated with Ni–W–SiO_2	------	------	823HV [116]
Steel coated with Ni-Co-SiO_2	$4.14*10^{-6}$ mm/y [117]	------	502 HV [117]
Steel coated with Ni-Al_2O_3	-----	18.7 mg/min [118] $2.44*10^{-4}$ mm^3/N-m [106]	905.4 HV [118] 641 HV [100]
Steel coated with Ni-Cu/ Al_2O_3	-----	------	570HV [111]
Steel coated with Ni/SiC	-----	$5.29*10^{-4}$ mm^3/N-m [92]	495 HV [92]
Steel coated with Ni-SiC/ Al2O3	-----	$4.95*10^{-4}$ mm^3/N-m [92]	525 HV [92]
Steel coated with Ni-Cr	-----	0.4 mg/h [109]	550 HV [109]
Steel coated with Ni–W/Cr_2O_3	-----	0.00670 mm/y [86]	602 HV [86]
Steel coated with Ni-Cu/ ZrO_2	0.066 mm/y [112]	------	6.193 GPa [112]

nanocomposite coatings has been studied for different kinds of reinforcements and matrix using different techniques, and every type was found to give certain corrosion character depending on the matrix and the content of the reinforcement in the matrix. Nanocomposite coating leads to improve some of the other properties (adhesion property, hardness, hydrophobicity, and distribution properties) which assist in enhancing the corrosion performance.

The challenges

Challenges of preventing agricultural machinery against corrosion and wear by using nanocomposite coatings.

- Corrosion research must be provided with information about the fundamental kinetics and mechanisms of the corrosion process for agricultural machinery.
- The research must be explained how the nanoparticles influence the matrix regarding aspects of the lattice structure, grain size, porosity, etc.
- The non-uniform distribution of the nanoparticles on the matrix of the coated layer leads to accumulating the ions and consequently, creates weak points of higher potential that cause pit initiation. So, the uniform distribution of the reinforcement must be achieved.

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تقليل تأكل البري وصدأ الآلات الزراعية بواسطة استخدام الترسيب الكهربائيللطلاءات النانومترية المركبة –بحث مرجعي

تتعرض الآلات الزراعية ومن ضمنها المحشات الترددية الى العديد من العوامل التي تؤدي الى تقليل العمر التشغيلي لها نتيجة حدوث تآكل ميكانيكي وتأكل كيميائي لتنوع الظروف التشغيلية لهذه الآلات ومن أهم هذه العوامل نوع التربة والظروف البيئية وايضا نوع النبات الذي يتم حصاده حيث تختلف محتويات النبات الكيميائية وايضا تختلف صلابة السيقان وقطرها ونسبة رطوبتها مما يؤدي الى تآكل سكاكين المحشات الترددية وزياده المطلوبة لقطع وحصاد المحاصيل المختلفة وتقليل العمر الافتراضي لهذه السكاكين مما يؤدي إلى زيادة القدرة.تكاليف التشغيل المتغيرةيوجد العديد من الأساليب المستخدمة لزيادة العمر الافتراضي للأجزاء الفاعلة في الآلات وتتعدد هذه الأساليب الي ابتكار مواد جديدة ذات مواصفات تقنية اعلي من مثيلتها المستخدمة وترسيب طبقة سميكة بواسطة تقنية اللحام وإضافة طلاءات بواسطة تقنية الترسيب الكهربائي ذات سمك صغير. وتعتبر الطلاءات النانومترية نوع حديث من الطلاءات المستخدمة للتغلب على ظاهرة التأكل في الآلات وذلك لاختلاف صفات المادة الكيميائية والميكانيكية والفيزيائية عند تصغيرها الي حجم النانو مما يؤدي الي تحسين الصفات المختلفة للطلاءات التقليدية.الترسيب الكهربائي للطلاءات.

تحديات تقليل التاكل الكيمائي وتاكل البري للالات الزراعية بواسطة استخدام النانومترية المركبة

-يجب تزويد أبحاث التآكل بمعلومات حول الحركية والآليات الأساسية لعملية التآكل.الزراعية الحادث في الالات

-يجب دراسة تاثير ادخال المواد في حجم النانو علي التركيب البنائي للطلاء و المسافات البينية للطلاء

- .يجب دراسة كيفية تحقيق التوزيع المنتظم للطلاء باستخدام المواد في حجم النانو لتحقيق الحماية الكاملة من التاكل في الالات الزراعية.