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Application of nanocomposite material to avoid injury by physical sports equipment

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Abstract. Safety in sports is important because if an athlete has an accident, he may not be able to lead an everyday life for the rest of his life. The safety of sports facilities is very effective in creating people's sports activities, with the benefits of staying away from physical injury, enjoying sports, and mental peace. Everyone has the right to participate in sports and recreation and to ensure that they want a safe environment. This study prepares a very good Nickel-Cobalt -Silicon carbide (Ni/Co-SiC) nanocomposite with convenient geometry on the leg press machine rod, employing the pulse electrodeposition technique to reduce the rod's wear and increase the durability of sports equipment and control sports damages. The results showed that the Ni/Co-SiC nanocomposite formed at 2 A/dm2 shows extraordinary microhardness. The wear speed for the Ni/Co-SiC nanocomposite created at 4 A/dm2 was 15 mg/min, showing superior wear resistance. Therefore, the Ni/Co-SiC nanocomposite can reduce sports equipment's wear and decrease sports injuries. Ni-Co/SiC nanocomposite layers with various scopes of silicon carbide nanoparticles via electrodeposition in a Ni-Co plating bath, including SiC nanoparticles to be co-deposited. The form and dimensions of Silicon carbide nanoparticles are watched and selected using Scanning Electron Microscopy (SEM).
Keywords: electrodeposition; Nickel-Cobalt alloy coating; silicon carbide nano-particulates; wear resistance

1. Introduction

Composite materials have played an essential role in human history, from building the first structures to helping advance today's technologies. Composites have influenced our daily life (Wu *et al*. 2021, Guo *et al*. 2022, Xu *et al*. 2022). A composite consists of two or more additional materials combined with various chemical and chemical virtues to achieve a purpose, such as increased strength, luster, or electrical resistance (Xia *et al*. 2020). To create composites, the materials are never dissolved in solution, and they can improve other properties such as durability and hardness. Composites are found in nature. Humans have used composite materials in different parts of the world for years (Elliott *et al*. 2021). The first time the composite dates back to 1500 BC (Han *et al*. 2022, Hao *et al*. 2022, Zhou *et al*. 2022b). When the inhabitants of Mesopotamia mixed mud and straw to build durable buildings, as a result, the resistance of brick blocks against bending, tension, and pressure increased (Erler *et al*. 2003). In general, a composite material has three components:

As a dispersed phase, reinforcements exist in different forms such as fibers, shells, and particles and have various characteristics. Fibers, reinforcing materials, have the most incredible impact on the automatic effects of the composite material (Xie *et al*. 2022, Zhang *et al*. 2022b, Zhu and Zhao 2022). The reason for this effect should be found in the high length ratio to the fibers' diameter, which creates therapeutic shear stress between this material and the matrix and gives the ability to process and produce composite parts in different shapes (Tang *et al*. 2021, Wang *et al*. 2021, Zhang *et al*. 2021).

As a continuous phase, the matrix connects the reinforcements and keeps them next to each other in a fixed position, preventing movement and distortion between the fibers (Li *et al*. 2022a, Sun *et al*. 2022, Zhou *et al*. 2022a). As a result, the amplifiers are resistant to physical and environmental damage. According to the type of structure, fibers or other reinforcements are placed in a specific position and then fixed by the matrix (Liang *et al*. 2021, Fang *et al*. 2022, Xuewu *et al*. 2022). Various materials such as polyester, epoxy, and phenol can be used as a matrix to construct a composite. Features such as corrosion resistance, electrical and thermal resistance, and flammability directly depend on the base material type (Guan *et al*. 2020, Bai *et al*. 2021).

Middle phase: A compressed matrix layer that forms on the surface of the reinforcement is called the middle phase, which is the interface between these two materials. The effect of this layer can be ignored for dispersed particles whose dimensions are in the range of microns. Nevertheless, nanoparticles have a wider surface and can occupy a significant percentage of the volume of the composite. Therefore, in reinforcements with dispersed nanoparticles, the intermediate phase affects the properties of the composite. Many outstanding properties of nano-composites, including yield strength, are due to the intermediate phase (Balázsi *et al*. 2003, Fischer 2003, Hernadi *et al*. 2003).

According to the type of matrix, composites are mainly placed in four groups:

Composites with metal matrix (MMC): The application

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of this type of composite is very high in the aerospace industry. Aluminum metal is used as a base with a lower density than iron to increase its resistance. Continuous carbon, carbide, silicon, or ceramic fibers are reinforcement in metal-based composites (Ye *et al*. 2008).

Ceramic matrix composites (CMC): In the construction of this product, ceramic or carbon fibers are surrounded by a ceramic matrix such as silicon carbide (Cho *et al*. 2009).

Composites with a matrix of organic, polymer, or reinforced plastic materials (PMC): This composite is made of short or long fibers connected by an organic polymer matrix. The main feature of this type of composite is to distribute the load between the fibers utilizing the matrix (Chen *et al*. 2017).

Using different materials to make composites can cover the weakness of each of them, strengthen their strengths and create new features. The resulting properties rely on agents such as the reinforcement's piece, size, and shape, the reinforcement, the phase distribution of the reinforcement, the mechanical properties of the matrix, and the interface between the matrix and the reinforcement (Xia *et al*. 2021). Composites resist corrosive and chemical substances and show their strength against water, moisture, and direct light, Unlike metals, which are equally strong in all directions and conditions, composites can be engineered and designed to be stronger in a particular direction (Shi *et al*. 2006). Electrical resistance depends on the type of materials used in the production of composites. For example, the composite made with insulating glass fibers, and the composite with carbon fibers is a conductor, very low thermal conductivity makes composites suitable for use as thermal insulation, one of the most prominent features of composites is high specific strength and modulus (Li *et al*. 2022b). In general, the remarkable features of composites include:

Ease of producing and making complex shapes with simple, efficient, and cost-effective methods. The ease of assembling parts, repair and troubleshooting operations, low thermal expansion coefficient, improvement of connections, and integrated production and energy absorption are suitable (Lee *et al*. 2004).

In current years, nanocomposite coatings retain existed constructed by combining nanoparticles in the metallic matrices to acquire improved possessions that resemble composite layers. At identical volume percentages, nanoparticles generate more useful advances in metal matrix effects than micro-sized particles. The co-deposition of nanocomposite layers is more complex than the co-deposition of composite coatings, including large particles, precisely due to the agglomeration of the particles (Vollath and Szabo 1999).

The efficiency of the nanoparticles is downward. Various techniques have been proposed to improve the nanoparticle incorporation in the composite layers, such as the operating sediment co-deposition method, the obtainment of surfactants, expansion of metallic cations, transforming the present method, using electrolyte agitation employing ultrasonic wave, and using two-step electrodeposition method (Tkalya *et al*. 2012, Bakhit and Akbari 2013).

Metal matrix nanocomposites contain dispersed second-phase particulates that usually include other unique custody such as diffusion hardening, self-lubricity, high-temperature inactivity, decay antagonism, and chemical and physical compatibility. This accounts for the raised application of Nickel-based nanocomposites in industry. Based on the studies, deposition plating is one of the exemplary processes for producing nanocomposites. Electroplating is an electrodeposition method that is employed to make metallic layers on a substrate via the action of the electrical current from an external reference (Malaki *et al*. 2019).

Electrodeposited Ni-Co/ ceramic nanoparticles composite coatings include more increased stability and hardness, precise magnetic properties, more useful chemical strength, and more suitable wear and erosion antagonism at high temperatures than the Ni-Co alloy coating since the composite layers mix the benefits of the electrodeposited Nickel-Cobalt layer and the ceramic nanoparticles (Safavi *et al*. 2020). Ni-Co alloy-based electrodeposited layers as a type of high-temperature wear-resistant and anticorrosive layer would be significantly dilated in harsh conditions, including water or caustic mixtures, which may induce intense wear and oxide climbing at high temperatures (Ababsa *et al*. 2022). The well-dispersed nano-sized Silicon carbide particles in a Nickel-Cobalt matrix cannot just improve the automatic effects but too would be required for service as composite materials in microdevices. Most of the helpful information in this regard emphasizes the Sic powders in size of a micron, and so far, no position exists noted in practice, and routine analysis of Nano-sized Sic supported Ni-Co composite coatings (Kamel *et al*. 2021). Silicon carbide nanoparticles show increased thermal conductivity, resilience, probity, good wear resistance, and a little thermal growth coefficient. These particles are too invulnerable to oxidation at elevated temperatures (de Vries *et al*. 2021). Silicon belongs to Block P, Period 3, while carbon belongs to Block P, Period 2 of the periodic table. An essential fact to be mentioned concerning their hold is that they must be saved from wetness, warmth, and pressure. Silicon carbide nanoparticles occur as a gray-white powder with a cubic morphology (Lee 1994).

Sport is a physical activity that is done to create health and also increase physical fitness. The safety of sports facilities is very effective in creating people's sports activities, with the benefits of staying away from physical harm, enjoying sports, and mental peace for people. Everyone has the right to participate in sports and recreation and to ensure that they enjoy a safe environment. Managing and solving issues that may arise plays the most critical role in creating a safe environment. Sports facilities must have all safety equipment, including first aid boxes, safe sports equipment, and a safe place for sports. In sports such as bodybuilding, where hefty tools and equipment are used, it is necessary to ensure that they are healthy and resistant to impact and corrosion.

Sports damages can be underrated by employing the right tools and keeping them in fine shape. Therefore, an ideal coating material can protect the surface of sports supplies to stop sports damage and enhance the durability of the tools Nickel-based ceramic nanoparticle coating, a nanomaterial for improving the wear and erosion opposition of sports supplies, is one of the numerous expedients and defensive crossbred layers for this tools also showed an increased group of drop resistance, which helps decrease sports damages induced by writing slipping (Martin *et al*. 2018, Bai and Li 2022).

The purpose of this procedure is to investigate the Effects of electron deposition parameters and properties of Ni-Co/SiC nanocomposite layers using the sediment co-deposition method on sports equipment to reduce injuries.

2. Experimental

2.1 Materials

This method aims to synthesize nanocomposite Ni-Co/SiC for sports equipment, especially in weight lifting, where a series of materials and solutions have been used in Table 1. Analytical reagents and distilled water were employed to design the plating solution.

2.2 Synthesis of sic using sol-gel process

Silicon carbide in commercial quantities The Acheson process makes the most. This process combines high purity silica sand with lower sulfur coke, salt, and soil. The saw is formed in a big longitudinal column with carbon electrodes. by passing an electric current between the electrodes, a resistance is heated to nearly 2000-2500 °C for 24-48 hours. Its reaction is shown in Eq.1.

$$SiO_2 + 3C \rightarrow SiC + 2CO \quad (1)$$

This reaction is endothermic. After cooling, the mass is crushed and separated. The central part is milled, treated with acids and bases, magnetically de-ironed, and dried.

2.3 Guidelines for the synthesis of Nickel-Cobalt / Silicon carbide nanocomposite employing sediment co-deposition

Silicon carbide nanoparticles were dispersed in the electrolyte with the presence of saccharin. A saturated calomel electrode was employed as the reference electrode, while A platinum plate was employed as the anode. A rectangular copper plate and a surface roughness smaller than 0.03 mm were employed as the cathode substrate to be plated. The substrates were successfully passed in ethanol, and purified water for 15 min, activated in HCl for 60 s, bathed in purified water, and then dipped in the plating bath to let the electrodeposition of the target nanocomposite coatings. Electrodeposition was taken out in a 100 ml glass cup. The bath temperature was held at 50C, and the pH was changed with HCl and NaOH at about 4 ± 0.05. The deposition period was changed to attain a coating consistency of around 40 lm. After the electrodeposition method, the coatings were ultrasonically washed with distilled water for 5 min to release partly trapped nano-particles from the cathode surface. The sample tested by this nanocomposite here is the sidebars of the leg press machine, which is one of the widely used equipment in sports clubs (Fig. 1). The tribological behaviors of the electro-deposited nanocomposite coatings reciprocally sliding against the road were discussed in a rod design beneath the unlubricated state at space temperature and ambient air. The friction coefficient was registered constantly during the difficulties (Cao *et al*. 2022, Cheng *et al*. 2022, Fang *et al*. 2022, Zhang *et al*. 2022a, Zhao *et al*. 2023).

Table 1 List of used materials

No	Name of the material	Amount used
1	$CoSO_4$	20 g Liter^{-1}
2	$NiSO_4$	130 g Liter^{-1}
3	$NiCl_2$	20 g Liter^{-1}
4	Na_3C_6	30 g Liter^{-1}
5	H_3BO_3	30 g Liter^{-1}
6	SiC	1–30 g Liter^{-1}
7	Saccharin	8 g Liter^{-1}

Fig. 1 The leg press machine

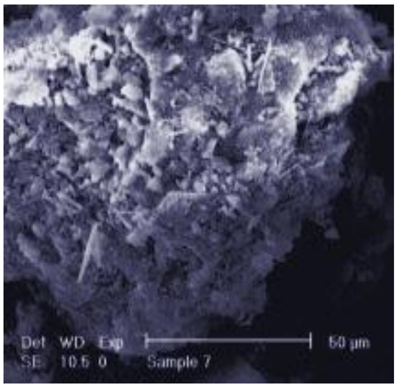
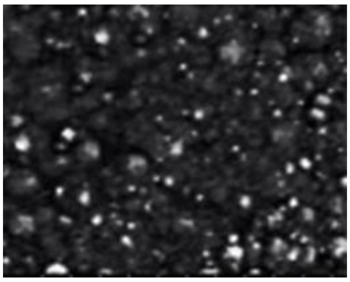


Fig. 2 SEM image of silicon carbide particles

3. Outcomes and debate

3.1 SEM seeing of silicon carbide Nano-particulates

SEM image of SiC particles, as can be seen, the powder particles are spongy, and the particles are agglomerated. The median length of the particles in the aggregation state reaches several microns (Fig. 2).


(a)

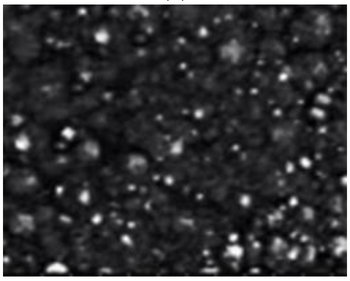

(b)

Fig. 3 (a) SEM Ni-Co alloy, (b) SEM Ni-Co/SiC nano-composite

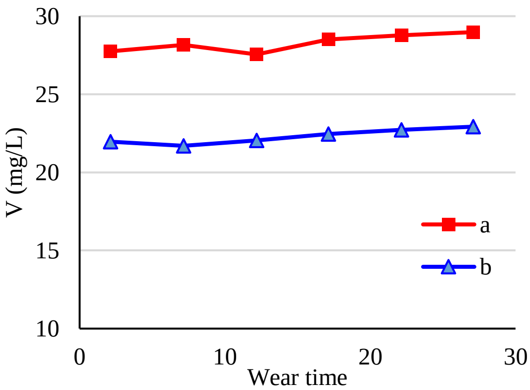


Fig. 4 Wear speeds of Ni/Co-SiC nanocomposites entrusted at various vibration current densities, (A) 2(A/dm^2), (b) 4(A/dm^2)

3.2 Morphology and stage format The Scanning Electron Microscopy pictures of the Ni-Co alloy and Nickel-Cobalt /SiC nanocomposite layers

Morphology and stage format The SEM pictures are shown in the shape of three surface morphologies of the Nickel-Cobalt alloy and Nickel-Cobalt/SiC nanocomposite layers. The plane of both layers exists as described via nodular morphology. Nevertheless, the nodule length of the nanocomposite layer is relatively less than the Nickel-Cobalt alloy layer due to the incorporation of the SiC Nano-particles into the Nickel-Cobalt alloy matrix (Fig. 3).

3.3 Wear rate

The wear speeds of Ni/Co-SiC nanocomposites deposited at various vibration current densities. The wear speeds were collected every 5 minutes, and then every two points were interconnected with a successive line (see Fig. 4). The considerable superior wear speed for a Ni/Co-SiC nanocomposite made at 2 A/dm2 was 29.4 milligram/min, as pictured in shape 4. However, the wear speed for a Ni/Co-SiC nanocomposite started at 4 A/dm2 was as nether as 15 milligrams/min, showing the increased wear antagonism of Ni/Co-SiC nanocomposites (Li *et al*. 2021, Si *et al*. 2021, Liu *et al*. 2022, Tan *et al*. 2022, Wang *et al*. 2022).

4. Discussion

Abrasion is one of the phenomena that neglect can cause financial and life losses. When two or more materials are in contact, some of the mass of one or both materials may be removed, in which case wear occurs. There are different types of clothes, and they can be made differently. A common type is an abrasive wear, which occurs when a hard object comes into contact with a soft object. This wear pertains to the rigidity of the two materials in communication. Using nanocomposites in sports equipment can help increase the life of this equipment and the health of athletes. The nanocomposite is a particular category of composites that at least one of their components is nanoscale.

In many cases in the industry, parts made of metal are constantly in contact and moving over each other. Also, an amount may be exposed to impact and collision with other materials. Sports equipment can also be exposed to wear and tear, and its resistance decreases over time. Ni/Co-SiC composites can replace standard materials used in tools, molds, and wear parts because they have high hardness and toughness. Ni/Co-SiC nanocomposite coating is one of the most crucial nanocomposite coatings. This coating has many applications in the automotive industry, engines, casting modules, sports equipment, etc., due to the protection of parts against wear caused by friction and high corrosion resistance. Microhardness is improved by reducing the size of SiC nanoparticles. Nickel and cobalt alloys have high wear resistance, corrosion resistance, and hardness. Other applications of this synthesized nano-composite in sports include reducing the corrosion of dumbbells and Bicycle iron pedal.

5. Conclusions

The purpose of making this nanocomposite and using it in sports equipment is to resist heavy use, high speed, substantial impacts, wear, and continuous movement. Sports safety gear and equipment may seem strange or unorthodox at times, but proper protective safety equipment is essential to prevent serious injuries or reduce the severity of an injury. Later, the purpose of a sport is to enjoy participating, and an injury can keep an athlete out of the sport for weeks or more. Here, using nickel nanocomposite can reduce the severity of damages that may be caused to athletes by using sports equipment. Different companies can prepare SiC nanoparticles, or the researcher can synthesize them in the laboratory. The SEM image of SiC particles synthesized in this work shows that the particles are spongy powder, and the particles are agglomerate. The middle dimensions of the particles in the aggregation state reach several microns. Shell morphology of Ni-Co alloy and Ni-Co/SiC nanocomposite layers by SiC photos shows that the surface of both layers with nodular morphology and the nanocomposite coating nodule due to the integration of SiC nanoparticles in the Ni-Co alloy matrix is relatively less. It is made of a Ni-Co alloy layer. Using this nanocomposite in a foot press machine to reduce wear over time shows that the superior wear speed for the Ni/Co-SiC nanocomposite created at 2 A/dm2 is 29.4 mg/min.

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