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An Overview of the Current State and the Advantages of using acrylic resins as anticorrosive coatings

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ABSTRACT
Corrosion protection coating is one of the most common ways of protecting structures against all kinds of negative external influences. Various types of anti-corrosion coatings can be used to successfully extend the service life of products. However, conventional paints are not water-resistant coatings, and small cracks always appear over time due to temperature fluctuations. Compared to other types of coatings, acrylic coatings are less expensive and just as durable. Acrylic resins have high anti-corrosion properties as well as water resistance, impact resistance, good adhesion to the substrate and overall durability. This powerful combination of cost and performance makes acrylic coatings such a popular and sensible solution for protecting structures against corrosion. The main purpose of this review is to describe the different types of acrylic resins and compare their properties, synthesis and drawbacks. It is expected that this work will be the cornerstone for the future development of acrylic resins.
Keywords: acrylic resins, corrosion, anti-corrosion coatings.

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Introduction

Over the past decades, many effective methods have been developed to reduce or minimize various types of corrosion [1].

Coatings today are one of the most effective methods of corrosion protection for both metal and non-metal surfaces [[2], [3]].

For high anti-corrosion protection, coatings should be: with high mechanical characteristics, good adhesion, durability and low moisture permeability.

Acrylate polymers have high transparency [4], good adhesive properties [5], a number of monomer species [6] and high mechanical strength, and therefore have aroused great interest.

Acrylic resin coatings (ARCs) are a reliable anti-corrosion tool as they are resistant to adverse weather conditions and are therefore used to control atmospheric corrosion. Such coatings are oil resistant and have high mechanical strength [7].

Acrylic resin is made from water-based acrylic polymers by solution or suspension polymerization; therefore, when used, it may be liquid or solid. It has been designed to minimize the dispersion and release of hydrocarbons; thus, reducing the content of volatile organic substances. The ingredients used to crosslink the acrylic resin determine the properties of the anti-corrosion agent used for the coating. The aim of the present review is to describe the best technology to protect metal from corrosion based on different acrylic resins to produce anticorrosion coating.

Properties, advantages and application of acrylic coatings

Acrylic coatings have the following protective properties:

- Transparent, glossy appearance and color stability;
- Relatively good resistance to weathering, chemicals, heat and solvents;
- Efficiency and flexibility;
- Excellent physical hardness and good adhesion;
- Fast drying and the ability to apply the pigment at ambient temperature.

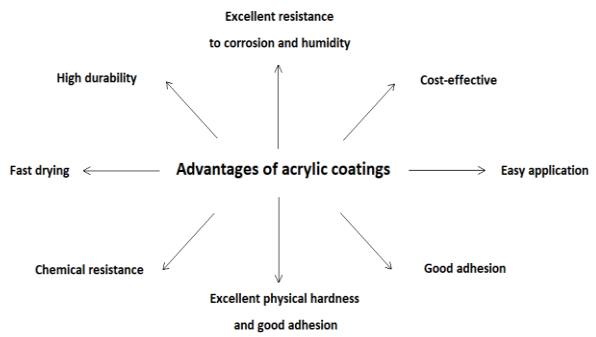

Figure 1 – Advantages of Acrylic coatings [[8], [9], [10], 11]].

Advantages of acrylic coating are illustrated in Figure 1. Acrylic resins have properties such as gloss retention [8], color retention [9], heat resistance [10] and corrosion resistance [11], so due to these properties, they are widely used in industry. They are used in automotive coatings and architectural coatings.

There is an acrylic urethane coating that has a high solids content and is used for auto repair work. This coating was made from acrylic and methacrylic and is a clear coat that cures at room temperature and exhibits very good overall performance [12].

Acrylic was also able to find application for the protection of museum items and monuments [13].

Acrylic resins are self-cleaning and therefore have found use in automobiles, buildings, and self-cleaning windows, which were synthesized to prevent or remove dirt by Yang et al [14].

In addition, acrylic resins are used as a protective material for paper, wood, ceramics, and glass [15].

But it is worth noting that its quality also depends on the composition of acrylic coatings. For example, if fillers are included in the composition of such coatings, this will increase their strength. If these fillers are properly dispersed in internal structures, they occupy micropores and this reduces the paths through which corrosive electrolytes pass through the coatings. Many coatings are compatible with fillers - barite, dolomite, silicon dioxide and others. But there are problems such as choosing the appropriate filler that is suitable for many inorganic and organic coatings.

Waterborne acrylic resins

Waterborne acrylic base coating as a single coat is used in various fields on account of its interesting properties such as high resistance to weather and different solvents as well as their excellent appearance [16].

Water-based acrylic resins in most cases copolymerize with acrylic, methacrylic acids and their esters, and their properties are adapted by adjusting the composition and ratios of different monomers as well as the structure of the starting materials.

There are several ways to synthesize water-based acrylic resin, which include emulsion, solution polymerization, bulk and suspension polymerization, emulsion polymerization being the most used. Synthesis occurs with monomers, water, emulsifiers and initiators [17].

Water-based acrylic resin, reacting with the appropriate filler, forms a solid mass, which in a short time reaches mechanical characteristics several times higher than classic water-based products. 50% mechanical performance is achieved after 15 hours at around 20°C. The acrylic system can be filled with iron oxide pigments, aluminum powder or various inert fillers to give the product the desired appearance. The addition of various fillers proportionally reduces the mechanical properties of the product.

Water-based coatings have greater advantages than coatings based on organic solvents [[18], [19],

[20], [21], [22], [23], [24], [25], [26]]. Such water-based coatings have low toxicity, are fire-resistant, and are environmentally friendly, which has attracted attention in the industry [[27], [28], [29], [30]]. Such coatings are increasingly used in the construction and paint industry, in metal and wooden coatings in order to reduce the emission of harmful substances [31].

But such coatings have a number of disadvantages, such as low chemical resistance and low water resistance, poor thermal stability, and low mechanical properties, despite this, water-based acrylic resins have become commercially available in recent years [32]. Applying modification and compounding can eliminate these shortcomings.

Water-based acrylic resins have a number of excellent characteristics and is applied in various aspects of production in connection with environmental protection. Such coatings are also used in the automotive industry, in the production of furniture and plastic parts, as well as in the anti-corrosion treatment of metals [17].

Acrylic coatings with various nanofillers

Nanoscale materials like TiO_2, SiO_2, ZnO and Fe_2O_3 are used to create hybrid organic coating systems [[33], [34], [35], [36], [37]]. When using mixed nanoparticles, it entails a synergistic effect and, in addition, improves some properties of the polymer. But, due to the high surface energy of nanoparticles, it allows easy agglomeration in some solutions [38]. In order to reduce the effect of the two-phase interface and to increase the stability and compatibility of nanoparticles in various media, modification of nanomaterials is required. Most researchers have found that the addition of nanoparticles can improve polymer characteristics [33-37], however, further research is needed on the synergistic effect of mixed nanoparticles and the improvement of polymer properties.

In studies of polymer and coatings, it was found that if such nanoparticles as TiO_2 [[39], [40]], ZnO [[41], [42]], Fe_3O_4 [43], SiO_2 [44], as well as their nanohybrids [[45], [46], [47]], then this, in addition to improving the various properties of the coating, also give new functions. For example, if a SiO_2 nanoparticle is added to the coating composition, this will improve the mechanical and thermal properties, as well as the anticorrosion properties of the organic coating [[48], [49], [50], [51], [52], [53]]. In addition, such nanoparticles were used for superhydrophobic [[54], [55], [56], [57], [58]] and hydrophilic coatings [59].

Acrylic polyurethane coating reinforced by sio₂ nanoparticles

SiO_2 nanoparticles are synthesized by such methods as the steam method, the sol–gel method, and the thermal decomposition method [[60], [61], [62]]. In such methods, tetraethoxysilane and tetramethoxysilane are used as precursors in order to obtain SiO_2 nanoparticles. Such precursors make it possible to control the size, shape, and purity of SiO_2 nanoparticles. However, the finished material has a high cost and is not an environmentally friendly process. Recent works have suggested more environmentally friendly approaches to obtain nano- SiO_2 using agricultural waste [[63], [64], [65], [66], [67]]. For example, rice husk is an agricultural waste that contains a large amount of silica (about 80–90 wt. %) [68]. Therefore, the use of rice husks to produce nanosilica has a high potential, since it is an environmentally friendly and cost-effective production, which, in addition, demonstrates rather high mechanical characteristics.

If the content of nanoparticles was increased from 0 to 2.5%, then this improved the mechanical performance as well. But, a higher addition of RHA-SiO_2 caused a decrease in mechanical properties. Many holes of different diameters from 20 nm to several microns appeared on the surface of the coatings and inside (without nano RHA- SiO_2), but the coating with 2.5 wt. % nano-GW- SiO_2 degraded less [69].

In the range of 200-400 nanometers, RHA- SiO_2 nanoparticles have high UV absorption. The nanocomposite coating is characterized by higher UV absorption compared to the pure one. Therefore, this suggests that if the nanocomposite contains nano-RHA- SiO_2, then this will scatter UV light and protect the half-dimensional matrix from the harmful effects of UV radiation. In acrylic polyurethane coatings, the photoprotective effect of RHA-SiO_2 nanoparticles is the same as in acryl melamine automotive varnishes [70].

The RHA- SiO_2 nanoparticle works like:

1) UV protector

2) as a nanofiller that screens and prevents the penetration of aging agents into the coating from the external environment.

This is evidence that such nanocomposite coatings are weather resistant.

Acrylic resin coating modified by functional graphene oxide

Carbon nanotubes (CNTs) are one of the most studied materials in recent years. CNTs are widely used in water treatment, biology, sensors, thin film transistors, and so on [71].

2 functional graphene oxide (FGO) was obtained by modifying the surface of graphene oxide (GO) with γ methacryloxypropyltrimethoxysilane (KN-570), then with acrylic nanocomposites with different loadings of GO and FGO. This is necessary in order to improve the dispersion and strength of the filler-matrix interface in acrylic resins [72].

To ensure that the coating effectively protects the substrate from the external environment and for good decorative properties, it is necessary that its adhesion to the given substrate is adequate. An adhesion tester is used to test the adhesion of a coating. It was maximum when the content of GO and FGO was 0.08 wt.%, since GO has a large specific surface area. With a small amount of GO, the surface energy of nanocomposites increases. Adhesion with FGO increased more than with GO. By adding FGO, the crosslink density increases, and the coating forms a 3-dimensional structure, and this leads to an increase in adhesion [73]. However, when adding GO and FGO more than 0.08 wt.%. adhesion is reduced. This manifestation may be due to the high agglomeration of nanoparticles, which led to the separation of the organic and inorganic phases and, therefore, GO and FGO do not play a significant role in adhesion [72].

Composites with both the addition of GO and the addition of FGO showed a high improvement in hardness. With the addition of 0.08 wt.% FGO and GO hardness increased by 64% and 41%. This phenomenon may be due to 2 reasons. The first reason is that GO has high mechanical properties. GO reduces the degree of surface deformation since it is well dispersed in the matrix resin. The second reason is that particles can be connected by different macromolecular chains and form physical / chemical crosslinks if a small amount of GO is added to the acrylic resin [74].

There was a comparison of the chemical resistance, water resistance, acid resistance, and alkali resistance of the nanocomposite coating. And a significant improvement in water resistance, acid resistance, and alkali resistance of coatings was found with the addition of FGO [72].

Characterization of anticorrosion zirconia/acrylic nanocomposite resin coatings

Using electrochemical methods, a study was made of the corrosion resistance of acrylic resin coatings that were modified with zirconium dioxide on steel substrates. Steel substrates coated with 3.5 wt.% NaCl were used for 1 and 7 days, at room temperature. From the impedance data, it was concluded that the corrosion resistance decreased as the ZrO_2NPs content increased. This was due to the oversaturation of the coating mesh and a decrease in the amount of base resin. If the concentrations are optimal, the modified zirconia particles act as a filler that reinforces the internal network of the coating and blocks the passage of the chloride ion that causes corrosion. But it should be noted that if the content of ZrO_2NPs in acrylic resin is more than 1 mg, the neutral electrolyte molecules will penetrate through the coatings due to the content of excess fillers, hence there is localized corrosion [75].

The content of modified ZrO_2NPs particles in the coatings of their acrylic resins blocks the penetration of corrosive chloride ions and water molecules through the coating to the metal surface, therefore it slows down local corrosion. Acrylic resin (10 g) contains the optimal concentration of ZrO_2NPs (1 mg) [76]. A change in the overall mechanical conductivity of the polymer coating was observed with the content of ZrO_2NPs nanoparticles. The average hardness value for the bare metal was 140 HV while the values for the coated samples were lower. This was due to the fact that nanoparticles act as inorganic fillers in the volume of acrylic resin coatings [75].

For each acrylic resin-coated substrate containing a ZrO_2NPs nanoparticle, the paths of corrosive ions and molecules that leaked onto the metal surface were blocked. Since the bulk porosity decreases due to particle dispersion, the protective effect will depend on the density of the filler particles and their concentrations [75].

Using the experimental data of this study, it can be concluded that if the content of ZrO_2NPs nanoparticles increases and the content of the main resin decreases, this will lead to a decrease in corrosion resistance. ZrO_2NPs nanoparticles (1mg) show excellent anti-corrosion ability in acrylic resin coatings [75].

Conclusion

Acrylic polymers are used as the main binder in a wide variety of coatings. Acrylic polymers increase the strength of coatings.

If these fillers are correctly dispersed in the internal structure of the coating, they will occupy their inherent micropores and, as a result, will reduce the paths where corrosive electrolytes pass through the coatings.

Many coatings are compatible with fillers such as calcite, talc, and silica. But there are still problems in choosing the right filler that is suitable for most coatings. Compared to other types of chemicals, acrylic coating is less expensive but more durable. Acrylic resins are widely used in industry due to their great properties such as strength [26], colour retention [27], heat [28], and corrosion resistance [29].

Conflict of interest.

On behalf of all authors, the correspondent author declares that there is no conflict of interest.

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Акрил шайырларын коррозияға қарсы жабын ретінде пайдаланудың артықшылықтарына және оның қазіргі кездегі жай-күйіне шолу

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ТҮЙІНДЕМЕ
Коррозияға қарсы жабын - құрылымдарды барлық жағымсыз сыртқы әсерлерден қорғаудың ең кең таралған әдістерінің бірі. Өнімдердің қызмет ету мерзімін ұзарту үшін коррозияға қарсы жабындардың әртүрлі түрлерін қолдануға болады. Дегенмен, әдеттегі бояулар суға төзімді жабындар емес, уақыт өте келе температураның өзгеруіне байланысты әрқашан кішкентай жарықшақтар пайда болады. Басқа жабын түрлерімен салыстырғанда, акрил жабындары арзанырақ және берік. Акрил шайырлары коррозияға қарсы жоғары қасиеттерге, сонымен қатар суға төзімділікке, соққыға төзімділікке, жақсы адгезияға ие және ұзаққа төзімді. Құны мен өнімділіктің бұлай сәйкес келуі акрил жабындарының құрылымдарды коррозиядан қорғау үшін өте жақсы таңдау екенін көрсетеді. Бұл шолудың негізгі мақсаты - акрилді шайырлардың әртүрлі түрлерін сипаттау және олардың қасиеттерін, синтезін және кемшіліктерін салыстыру. Бұл жұмыс акрилді шайырлар бойынша кейінгі зерттеулерді дамыту үшін өте маңызды кезең болады деп күтілуде.
Түйін сөздер: акрилді шайырлар, коррозия, коррозияға қарсы жабындар.

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Обзор современного состояния и преимущества использования акриловых смол в качестве антикоррозионных покрытий

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АННОТАЦИЯ

Антикоррозионное покрытие является одним из самых распространенных способов защиты конструкций от всевозможных негативных внешних воздействий. Для успешного продления срока службы изделий можно использовать различные виды антикоррозионных покрытий. Однако обычные краски не являются водостойкими покрытиями, и со временем всегда появляются небольшие трещинки из-за перепадов температур. По сравнению с другими видами покрытий, акриловые покрытия менее дорогие и такие же долговечные. Акриловые смолы обладают высокими антикоррозионными свойствами, а также водостойкостью, ударопрочностью, хорошей адгезией к основанию и общей долговечностью. Это мощное сочетание стоимости и производительности делает акриловые покрытия таким популярным и разумным решением для защиты конструкций от коррозии. Основной целью данного обзора является описание различных типов акриловых смол и сравнение их свойств, синтеза и недостатков. Ожидается, что эта работа станет краеугольным камнем для дальнейшего развития акриловых смол.

Ключевые слова: акриловые смолы, коррозия, антикоррозионные покрытия.

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