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Synthesis, Characterization, and Application of Polyurethane-Acrylic Hybrids as Anticorrosion Coatings

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Abstract. In the current study, the synthesis, and properties of polyurethane (PU) and acrylic copolymer (AK), as well as polyurethane/acrylic polymer hybrid (PU/AK), were examined. Polyurethane (PU) was synthesized by the polyaddition polymerization of isocyanates [Isophorone diisocyanate (IPDI) and hexamethylene diisocyanate (HDI)] and polyols (GP 2000 and GP 4000) at an NCO/OH ratio of 0.85 and a temperature of 100°C. The acrylic copolymer (AK) based on methyl methacrylate (MMA) and butyl methacrylate (BuMA) was synthesized using a bulk polymerization process using benzoyl peroxide as a catalyst. Polyurethane/acrylic hybrids (PU/AK) were created by combining PU with varying amounts of AK (5, 10, 20, 30, 40 wt.%). Several formulations were created to examine the impact of AK content on the physical and mechanical characteristics of PU/AK hybrid polymers, as well as the anticorrosion resistance of hybrid coatings (PU/AKC). To verify that the PU polymerization reaction had finished and to characterize AK, IR spectroscopy was used. The physical and mechanical properties of PU, AK, and PU/AK including viscosity, thixotropic index (TI), tensile, elongation, hardness, adhesion, contact angle, impact test, crosshatch, and anticorrosion properties were significantly affected by the concentration of AK. The viscosity, TI, tensile strength, hardness, contact angle, and adhesion increased with increasing concentration in the PU/AK hybrid. The cross-linking of PU and AK in the hybrids increases the mechanical characteristics. However, the hybrid coating containing 10% AK had the highest chemical and corrosion resistance compared to the other contents of AK and PU.

Keywords: Acrylic; Anti-corrosion; Coating; Hybrid; Polyurethane

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1. Introduction

The primary effect of metal corrosion in the oil and gas industry is to shorten the lifespan of numerous equipment, which can lead to significant financial losses and safety issues (Vakili *et al.,* 2024; Lawal *et al.,* 2023; Solovyeva, Almuhammadi, and Badeghaish, 2023; Bender *et al.,* 2022; Marathe and Gite, 2016). Since polyurethane polymers (PUs) are renewable and versatile resources, they have been employed in coatings to protect metals against corrosion and continue to play an essential role (Alshabebi *et al.,* 2024; Maurya, de-Souza, and Gupta, 2023; Patil *et al.,* 2021; Cao *et al.,* 2020; Negim *et al.,* 2020; Jiang *et al.,* 2019; Ur-Rahman *et al.,* 2018; Deng *et al.,* 2017; Syrmanova *et al.,* 2016). By adding polymerization between isocyanates and polyol, PUs are made (Ramezanzadeh *et al.,* 2015).

Anti-corrosion coating is a surface treatment that can be applied to both concrete and steel reinforcement. The primary purpose of concrete surface coating in terms of anti-corrosion is to reduce the penetration of aggressive agents such as carbon dioxide, chloride ions, oxygen, and water, or to lower the conductivity and corrosion rate of the concrete (Hu *et al.,* 2022).

PUs have achieved enormous success in the paint industry after being created to improve their mechanical and physical qualities (Yeligbayeva *et al*., 2024; Akhanova *et al.,* 2024; Syrmanova *et al.,* 2016). In the coating sector, some of the value of polyurethane resins has decreased due to the emergence of new polymers. Compared to polyurethane resins, the new coating materials had fewer volatile organic compounds (VOCs) and were based on water, which was the primary factor responsible for the environmental impact. In addition, the surface characteristics of water-based coatings might be adversely affected by their relatively high surfactant concentrations (Bartman *et al.,* 2023; Kurpanik *et al.,* 2022; Zhang *et al.,* 2021; Negim *et al.,* 2020; Negim *et al.,* 2019; Marathe and Gite, 2016; Butler, Fellows, and Gilbert, 2004). Also, polyurethane-water-based, and polyurethane-solvent-based have low mechanical and physical properties. To improve the properties of polyurethane, modified polyurethane resins are made of modifiers integrated into the polyurethane fiber structure by using a hybrid process. Performance improvements in the resultant materials are anticipated when acrylics and PUs are combined (Wang *et al.,* 2023; Lovato *et al.,* 2023; Bichu *et al.,* 2023; Yan *et al.,* 2023; Zhang *et al.,* 2020; Son *et al.,* 2011).

Acrylic and PU have advantages including high mechanical properties and excellent chemical resistance (Bui *et al.,* 2020). Styrene and (meth)acrylates are used to produce the most common hybrids with PUs. The primary goal of creating these hybrids is to combine the advantages of these different kinds of polymers to create materials with improved functionality. Polyurethane-acrylic latex has been extensively researched as a potential replacement for PU-based coatings (Zhu *et al.,* 2008). The unique characteristics of each component—PUs and polyacrylates—are combined to create the resulting copolymer. Positive attributes that are often desired include fast drying, good adherence to the substrate, high gloss of the PUs, oxidative drying, good film formation, and chemical resistance of the acrylic latexes. The incompatibility of hydrophobic polymeric units (PUs) and aqueous dispersions of acrylic polymers limits their use as blends in several applications. For instance, using incompatible.

PU-acrylate mixes often lead to decreased gloss and the formation of haze in films. In order to address this problem, polyurethane and acrylates are chemically bonded together to create PU-acrylic copolymer latexes. In contrast, Negim *et al.* (2024) combined polyurethane and 2-hydroxy ethyl acrylate to create polyurethane-acrylic hybrids with an NCO/OH ratio of 2.2. The findings showed that, in comparison to those of pure

polyurethane, the physical and mechanical qualities of the hybrids improved with an increase in the quantity of 2-hydroxy ethyl methacrylate. The structure of the pure polyurethane and the finished qualities of the PU were altered by the addition of the acrylic component to the hybrids (Peruzzo *et al.,* 2010). A 50% acrylic content exhibited the excellent properties of PU.

Anticorrosive nanocoatings provide significant protection for metals and alloys in different environments. They enhance functionality and extend shelf life by preventing corrosion from water, microbial biofilm formation, dirt, and other contaminants. These coatings also offer self-cleaning, antifouling, and active corrosion protection through self-healing. They are categorized into metallic, ceramic, and polymeric nanocoatings based on the matrix type, and graphene/carbon-based nanocoatings as nanofillers. Examples of commercialized anti-corrosion agents are also discussed below (Susai *et al.,* 2020).

Commercial anticorrosion products such as NanoTech HPC, NC-310, Supertemp 316, Superlife 316 DTMR, and Nasiol MP55 are available. NanoTech HPC generates covalent bonds, increasing pipes' strength and longevity by three to eight times. It offers hardness and elasticity, is 10–20 microns thick, and doesn't cause galling or seizing. It's used in the oil and gas sector to protect pipelines. NC-310 is a biologically modified ceramic coating used for anticorrosion on aluminum and other metals. Supertemp 316 and Superlife 316 DTMR are liquid stainless-steel coatings injected with 316L stainless steel flakes. The FDA and USDA propose these coatings for meat, poultry, and chicken processing plants. Nasiol MP55 is an ultratransparent, time-saving, and easy-to-clean nanocoating ideal for protecting metallic bodies and alloys from corrosion (Susai *et al.,* 2020).

In this study, PU was coated by a hybrid with an acrylic copolymer containing methyl methacrylate and butyl methacrylate at a feed composition of 5:5. The PUs were prepared based on a mixture of isocyanates and different polyols with an NCO/OH ratio of 0.85. The obtained acrylic copolymer and PU were characterized by FTIR. The mechanical properties of the PU/AK hybrid films were investigated. Additionally, the chemical and corrosion resistance of the PU/AKC hybrid coatings were tested through standard methods.

2. Experiments

2.1. Materials

Polypropylene glycol (GP-2000) (M_w = 2000 g/mol, OH number = 56 mg KOH/g), GP-4000 (M_w = 4000 g/mol, OH number = 29.5 mg KOH /g), GP-3000 (M_w = 3000 g/mol, OH number = 37 mg KOH /g), and GP-2100 (M_w = 3000 g/mol, OH number = 56 mg KOH /g) were purchased from Korea PTG, Korea and were dried at 80°C, and 1-2 mm Hg, for 2 h before use. Dibutyltin dilaurate (DBTDL), isophorone diisocyanate (IPDI), and hexamethylene diisocyanate (HDI) were purchased from Bayer AG, Germany.

Additionally, solvents including xylene, methyl ethyl ketone (MEK purity > 99.9%), hydrochloric acid (ACS reagent, 37%), sulfuric acid (ACS reagent, 37%), ethanol (ACS reagent 20%), and sodium chloride (ACS reagent 10%) were purchased from Sigma Aldrich, USA. The ESOL N100 plasticizer from VISTALINE in Russia and the BYK-054 defoamer from BYK in the USA were also used. Calcium carbonate (filler) and TiO2-R-996 (pigment) were purchased from Elementis in Malaysia and used without requiring additional purification.

2.2. Polyurethane Polymer Synthesis

The polyurethane polymer was prepared using the previously published methods (Wang *et al.,* 2023; Zhang *et al.,* 2020; Negim *et al.,* 2019). Polymerization took place in a 500 mL round-bottom, four-necked separable flask equipped with a drying tube,

condenser, and thermometer. In an oil bath at a constant temperature, the reaction was conducted in an N_2 environment. The di-n-butylamine titration technique was used to estimate the theoretical NCO value, which was attained after charging the reactor with isophorone diisocyanate (IPDI), hexamethylene diisocyanate (HDI), and polyols (GP 2000 and GP 4000) (ASTM D 2572). The mixture was then heated at 100°C for 3 h.

The polyurethane polymer was produced in the same manner as previously described in the literature (Wang *et al.,* 2023; Zhang *et al.,* 2020; Negim *et al.,* 2019). Polymerization was carried out in a 500 mL round-bottom, four-necked separable flask equipped with a mechanical stirrer, thermometer, condenser, and drying tube. The reaction took place in a constant-temperature oil bath in an N_2 environment. Isophorone diisocyanate (IPDI), hexamethylene diisocyanate (HDI), and polyols (GP 2000 and GP 4000) were added to the reactor, and the mixture was heated at 100°C for 3 hours until the theoretical NCO value was attained, as evaluated by the di-n-butylamine titration technique (ASTM D 2572-19, 2019). Figure 1 depicts the reaction method used to prepare the prepolymer. Table 1 displays the samples that were made. The resulting PU was clear and liquid, with viscosities of 120 mPa-s and 464.4 mPa-s at 5 and 50 rpm, respectively.

Table 1 Crystal size of heterogeneous catalyst using Debye-Scherrer Equation

	Wt (g)		Wt (%)
Polyols, OH			
GP 2000	168.5		82.2
GP 4000	21.6		10.5
Total	190.1		92.7
Mole of OH (gm/ mole)		0.0896	
Isocyanate, NCO			
IPDI	8.5		4.1
HDI	6.4		3.1
Total	14.9		7.3
Mole of NCO (gm/mole)		0.0762	
NCO/OH		0.85	

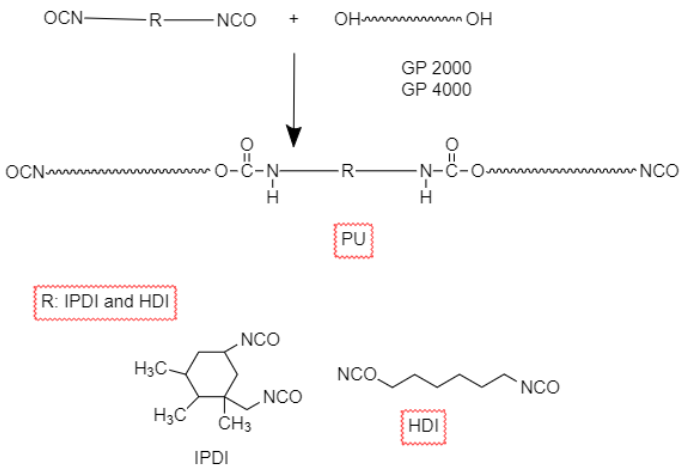

Figure 1 The reaction scheme for the preparation of PU

2.3. Synthesis of poly(methyl methacrylate-co-butyl methacrylate) (AK)

The copolymerization of methyl methacrylate (MMA) in conjunction with butyl methacrylate (BuMA) in feed (5/5) was prepared by the bulk polymerization technique. The two monomers MMA and BuMA were added to a 250 mL three-necked flask. Using an

automatically regulated water bath in an atmosphere of nitrogen, benzoyl peroxide was introduced to the flask and mechanically stirred for 3 h at 500 rpm and 82°C. The copolymer obtained was analyzed using FTIR to confirm its structure and functional groups. The MMA-co BuMA was liquid and transparent in appearance with viscosities of 432 mPa-s and 600 mPa-s at 5 and 50 rpm, respectively.

2.4. Preparation of polyurethane/acrylic hybrids (PU/AK)

Polyurethane/acrylic hybrids were prepared by mixing process at temperatures 60°C and 600 rpm. Further details about the PU/AK hybrids are given in Table 2.

Table 2 The composition of the PU/AK hybrids

Samples	Polyurethane polymer Wt., (gm)	Poly MMA-co BuMA Wt., (gm)
PU	100	0
PU/AK-5	95	5
PU/AK-10	90	10
PU/AK-20	80	20
PU/AK-30	70	30
PU/AK-40	60	40

2.5. Preparation of PU and PU/AK hybrid films

PU and PU/AK films were created by casting the solution onto a flat surface and allowing it to cure for five days at room temp. The films were stored in a desiccator at room temperature for subsequent characterization and measurement.

2.6. Preparation of the PUC and PU/AKC coatings

To prepare the PUC and PU/AKC coatings, the weight percentages of the coating ingredients can be found in Table 3. In all formulations, the solid content of PU or PU/AK accounted for 27% of the total mixture. Xylene and polyols (GP-3000 and GP-2100) were combined in a vial and mixed for 10 minutes at a speed of 500 rpm. After adding the plasticizer ESOL N100 and the anti-foam BYK-054, the mixture was stirred for five minutes. Calcium carbonate (filler) and TiO_2-R-996 (pigment) were added to the mixture and continued to mix for 30 minutes at 1200 rpm. Finally, DBTL (catalyst) is added during the application of the coating on the metal.

Table 3 The composition of the PU/AK hybrids

Raw materials	Weight percent
PU or PU/AK	27
Xylene	6.45
GP-3000	9.24
GP-2100	4.5
ESOL N100	4.5
BYK-054	0.35
Calcium carbonate	40.16
TiO_2-R-996	4
DBTDL	0.4
Total	100

2.7. Application of the PU and PU/AK as coatings

Before applying the coating, the metal samples with dimensions of 9.0 cm x 0.9 cm x 15 cm were subjected to abrasive blasting and cleaning. The coating, which was based on PU and PU/AK, was applied using a film applicator to achieve a wet film thickness of 75 mm. The samples were then allowed to cure at room temperature for a period of 6 days.

2.8. Tests

FTIR spectra were obtained with a Bruker Tensor 37 FTIR spectrometer. The Y-axis, which represents the percentage of transmittance difference between the signals, might be utilized in calculating the transmittance %. Additionally, software that automatically calculates and shows the % transmittance vs wavenumber (or wavelength) for the whole spectrum is included with the majority of modern FTIR spectrometers. The viscosity (η) of the PU, AC, and PU/AC hybrids was measured using a Brookfield viscometer, Spindle 2, at speeds of 5 and 50 rpm at 25°C. The thixotropy index was obtained using equation 1;

$$\text{Thixotropy index (TI)} = \eta_5/\eta_{50.} \quad (1)$$

To determine the contact angle between the water droplets and the sample surface, a CAHN DCA-322 contact angle measuring device was employed. It was run at 25°C with a water drop and a velocity of 100 lm/s. A little syringe was used to deposit a drop of water on the surface to be investigated, and the contact angle was measured by watching the water drops form on the monitor.

The findings were obtained by averaging three measurements performed on separate portions of the film. The tensile properties of the cast films were evaluated using an MTS 10/M tensile testing system with a crosshead speed of 50 mm/min. A minimum of four values were averaged, and a 1-kN load cell was utilized. Furthermore, an indentation Barcol hardness tester was used to evaluate the hardness in accordance with ASTM B648-10. Pull-off testing was used to determine the degree of adhesion between the metal and hybrid polymers in accordance with ASTM D4541. Tests for corrosion resistance were carried out on coated panels using salt (10% NaCl), base (10% NaOH), acid (37% HCl and H_2SO_4), solvent resistance (xylene, MEK, and ethanol) (ASTM D5402-93), and water resistance (D1647-89). A temperature of 25°C was used to record the dry times.

3. Results and Discussion

3.1. FTIR analysis

The success of the addition polymerization of isocyanate (NCO) with polyol (OH) was evaluated by FTIR spectroscopy as shown in Figure 2. According to the FTIR spectrum of pure isocyanate (Figure 2a), the observed that the transmittance of NCO peak at 2243 cm^{-1} was 95%, which decreased to 15% at 2261 cm^{-1}, as shown in Figure 2b for polyurethane, which was attributed to the consumption of OH group of polyols (GP 2000 and GP 4000) for 80% of the NCO during the addition polymerization. The new peaks observed in Figure 2b for the polyurethane polymers were at 2867-2930 cm^{-1} for CH_2, and at CH_3, and 1091 cm^{-1} for the ether group (C–O–C) due to the polyol groups. The structure of PU is shown in Figure 1.

The FTIR spectrum of poly MMA-co BuMA is shown in Figure 3. The FTIR spectrum of the copolymer showed a peak at 1732 cm^{-1} for the carbonyl group, peaks at 2960 and 3437 cm^{-1} for CH stretching, and a peak at 1273 cm^{-1} for the (C–O–C) ester group. The structure of the copolymer is shown in Figure 4.

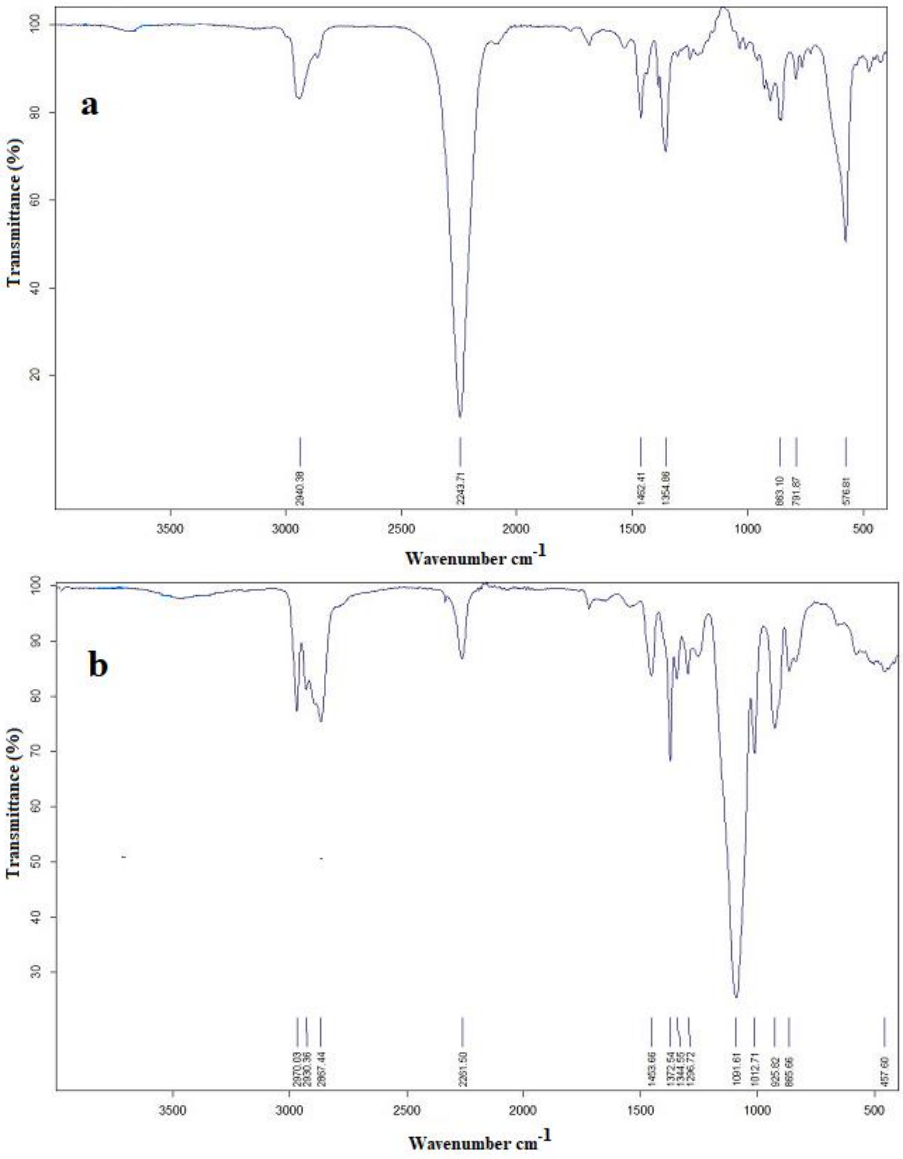

Figure 2 FTIR spectra of (a): pure isocyanate and (b) PU

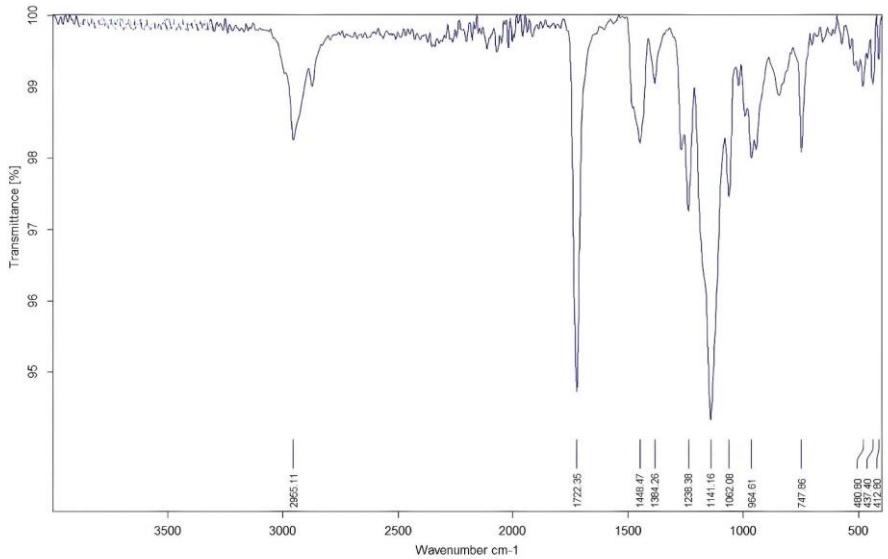

Figure 3 FTIR spectra of MMA-co-BuMA

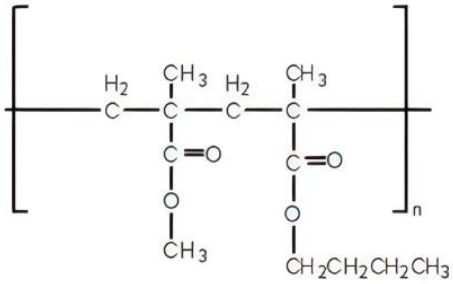

Figure 4 Structure of Poly MMA-co-BuMA

3.2. Viscosity and thixotropic index (TI)

The effect of the content of poly (MMA-co-BuMA) on the viscosity of the polyurethane/acrylic hybrid at speeds of 5 and 50 rpm is shown in Figure 5. The viscosities of PU were 464 mPa-s and 120 mPa-s, while the viscosities of poly (MMA-co-BuMA) (AK) were 432 mPa-s and 600 mPa-s at 5 and 50 rpm, respectively. Generally, the rheology study of the polymer indicated that the viscosity of the polymer decreased as the rpm increased because of the shear-thinning nature of the polymer (Wang *et al.,* 2020). The viscosity of PU/AK increased with increasing AK content in the PU/AK hybrids. PU/AK-5 had the lowest viscosities of 453 mPa-s and 110 mPa-s at 5 and 50 rpm, respectively, while PU/AK-40 had the highest viscosities of 770 mPa-s and 180 mPa-s at 5 and 50 rpm, respectively. The higher molecular weight of the hybrids may be the cause of the increase in viscosity (Nanda *et al.,* 2005).

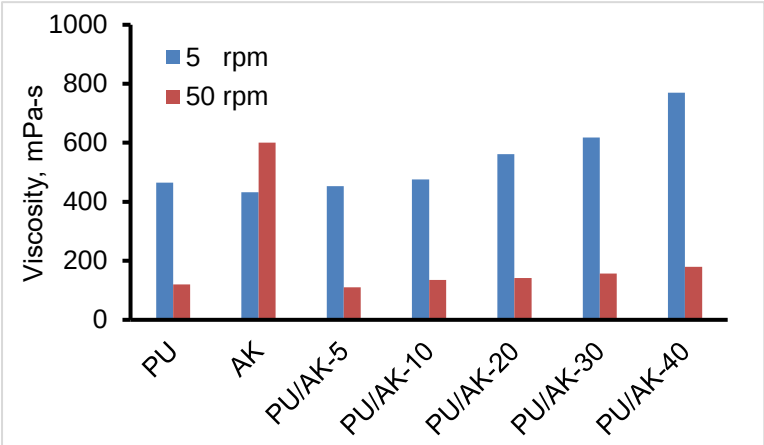

Figure 5 The viscosity of PU/AK hybrids at speeds of 5 and 50 rpm

The thixotropic index (TI) is a significant factor in controlling the quality of a polymer for coating applications. The thixotropic index of PU was 3.87, while it was 0.72 for AC, as shown in Figure 6. The mixing of AK with PU to produce a hybrid polymer increased the TI from 3.87 to 3.9 for PU/AK-20 and PU/AK-30 and to 4.2 for PU/AK-40, which is greater than the standard for coating applications (TI = 3.0). The thixotropy of the coating influences the formulation and preparation process of the coatings and in turn, affects the rheological properties of the coating (Wang *et al.,* 2022).

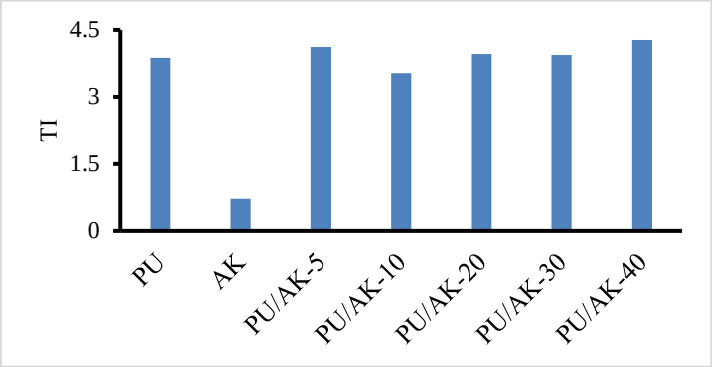

Figure 6 The thixotropic index (TI) of PU/AK at different ratios

3.3. Adhesion

The adhesion of polyurethane on the metal is a result of adsorbate layers as well as chemical bonds between isocyanate and metal surface involving the chemical process. There are many factors that affect the adhesion of polyurethane including isocyanate content, polyol, and acrylic polymer (Ito *et al.,* 2020; Nacas *et al.,* 2017). The effect of AK on the adhesion of the PU/AK hybrid on the metal is shown in Figure 7. The results revealed that the combination of AK with PU influenced the adhesion of the PU/AK hybrids to the metal. The adhesion of PU to the metal was 3.2 MPa, and that of AK to the metal was 2.1 MPa. The combination of AK with PU to produce a PU/AK hybrid increased the adhesion of the PU/AK hybrids to the metal. Increasing the concentration of AK in the hybrid by 5 to 20% increased the adhesion strength from 4.5 MPa to 6.9 MPa. More than 20% of the adhesion of the hybrid decreased to 4.6 MPa, which was still higher than that of PU. The increase in the adhesion is attributed to the crosslinking between PU and AK as shown in Scheme 4, while the decrease in adhesion is due to the influence of 30% and 40% AK on the linking between hybrids and the surface of metal (Leitsch, William, and John, 2016). Figure 8 illustrates the crosslinking between PU and AK as well as the functional group (NCO) on the substrate which is responsible for the increase in adhesion (Negim et al., 2016; Lei *et al.,* 2015).

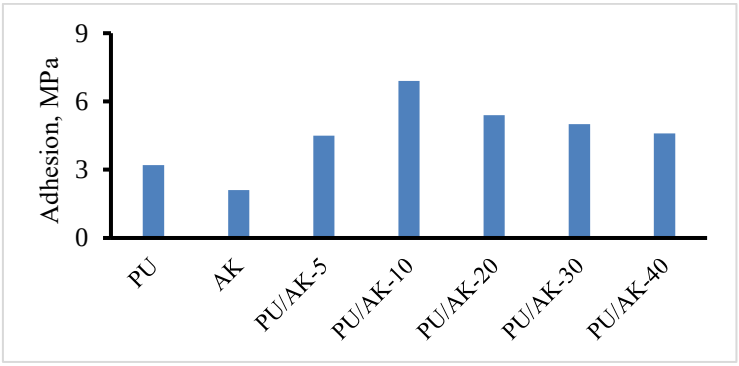

Figure 7 Adhesion of PU/AK on the metal

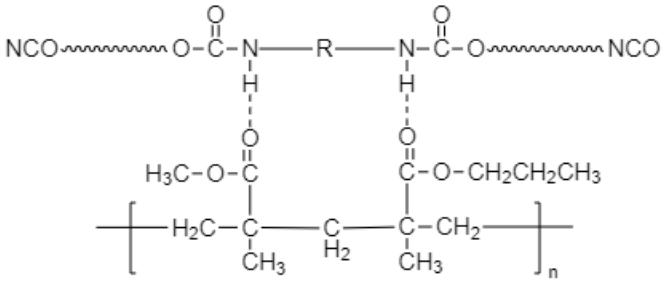

Figure 8 The cross-linking between PU and AK in the PU/AK hybrid

3.4. Mechanical Properties

The chemical properties of polymers are determined by various factors such as the type of monomer, material, solvent, temperature, crosslinking, and concentration. Table 4 shows the impact of AK on the PU/AK hybrid. When AK is mixed with PU to create a hybrid, it enhances the tensile strength, hardness, and contact angle, while reducing the elongation at break. The increase in the mechanical properties of PU/AK is affected by the length of the side chains through the hydrogen bonds between PU and AK as shown in Scheme 4. For example, the tensile strength of PU was 75 MPa, while PU/AK enhanced tensile strength to 97 MPa for PU/AK-5 and 201 MPa for PU/AK-40. Furthermore, hardness (shore D) increased from 45 for PU to 68 for PU/AK-40. The impact test was passed for all samples except AK, which passed the crosshatch test. PU/AK had better mechanical properties than PU, AK, and other PU/AK hybrids due to the two kinds of cross-linking between PU and AK. A number of researchers have reported that crosslinking the backbone of a polymer is an effective way to increase the mechanical properties of polymer films (Lei *et al.,* 2015).

Table 4 Mechanical properties of the PU and PU/AK hybrids

	Tensile strength, MPa	Elongation, %	Hardness, shore D	Contact angle	Impact[a] test	Cross[b] Hatch
PU	75	200	45	105	Pass	Pass
PU/AK-5	97	158	50	120	Pass	Pass
PU/AK-10	164	125	53	132	Pass	Pass
PU/AK-20	180	110	58	140	Pass	Pass
PU/AK-30	186	106	63	145	Pass	Pass
PU/AK-40	201	95	68	147	Pass	Pass

[a]: A test used to assess the adhesion of paint coatings and provides an instant assessment of the quality of the bond to the substrate

[b]: A test used for assessing the durability and resilience of powder coatings

3.5. Chemical and corrosion resistance

Table 5 illustrates the impact of the AK component on the chemical and corrosion characteristics of hybrid coatings (PU/AKC). These characteristics include resistance to solvents, acids, alkaline substances, water, and salt coatings. The results indicate that the polyurethane coating is effective against alkaline, water, and ethylene glycol solutions. However, the addition of AK in the PU coating enhances corrosion and chemical resistance. The hybrid coating PU/AKC5 (5% AK) is suitable and slightly suitable for most chemical and corrosion treatments. Increasing the AK content to 10% increased the corrosion resistance of the coating hybrid. Out of all the evaluated samples, PU/AKC10 showed the best resistance to chemicals and corrosion. Table 5 illustrates how the hybrid coating's resistance to chemicals and corrosion was reduced when the amount of AK in the hybrids

increased. The coating's adherence to the metal is what causes its corrosion resistance to grow and decrease (Negim *et al.,* 2020; Wang *et al.,* 2019; Kozakiewicz, 2015; Madbouly and Otaigbe, 2005).

Table 5 The effectiveness of the hybrid coating (PU/AKC) against corrosion and chemical resistance was reduced when the amount of AK in the hybrids increased

	PUC	PU/AKC5	PU/AKC10	PU/AKC20	PU/AKC30	PU/AKC40
	Corrosion resistance					
NaCl (10%)	Δ	O	O	Δ	Δ	Δ
NaOH (10%)	O	O	O	Δ	Δ	Δ
HCl (37%)	X	Δ	O	X	O	X
H_2SO_4 (37%)	X	Δ	Δ	Δ	O	X
Ethylene glycol	O	O	O	O	O	O
Wine	X	Δ	Δ	Δ	Δ	X
Acetone	X	Δ	Δ	Δ	Δ	X
Butyl alcohol	X	Δ	Δ	X	X	X
	Chemical resistance					
MEK	X	Δ	Δ	Δ	X	X
Xylene	O	O	O	Δ	Δ	X
Ethanol (20%)	X	Δ	O	Δ	Δ	X

O: Suitable
Δ: Slight Suitable
X: Not Suitable

4. Conclusions

The study coated PU with a 5:5 acrylic copolymer containing methyl and butyl methacrylate, prepared from isocyanates and polyols with a 0.85 NCO/OH ratio. FTIR characterization was used to investigate mechanical properties and chemical and corrosion resistance of the PU/AK hybrid films. Polyurethane (PU) was prepared from a mixture of isocyanates (IPDI and HDI) and different polyols (GP-4000 and GP-2000) using the polyaddition technique, while acrylic copolymer (AK) was synthesized by a bulk technique based on methyl methacrylate and butyl methacrylate. Polyurethane and coating hybrids were created by mixing PU with varying amounts of AK in order to investigate how AK content affected the hybrid films' mechanical and physical characteristics as well as their resistance to chemicals and corrosion. AK and UP together improved the mechanical and physical characteristics of the polyurethane/acrylic hybrids because they include functional groups that come from PU and AK, such as NCO, NH, carbonyl, and ester groups, which may cause cross-linking between UP and AK. The tensile strength, adhesion, hardness, and contact angle of the PU and AK hybrids were all higher than those of the pure PU and AK. But when the AK concentration rose, the tensile strength, adhesion, contact angle, and hardness all improved while the elongation at break reduced. This is primarily explained by the polymeric network that PU and AK cross-linked to produce the hybrid polymer. However, the coating hybrids exhibited the best chemical and corrosion resistance when the PU/AKC hybrids contained 10% AK. PU/AK hybrid polymers could offer enhanced anticorrosion resistance and mechanical properties, making them ideal for various industries. They are suitable for protective coatings on metals, construction adhesives, aircraft components, marine environments, bridges, pipelines, electronic components, and industrial packaging materials. These properties make them suitable for durability, chemical resistance, mechanical strength, and anticorrosion protection in various industries. Future research on polyurethane-acrylic hybrids as anticorrosion

coatings should focus on long-term durability, aging studies, eco-friendly alternatives, and industrial application, aiming for sustainable solutions.

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Conflicts of interest

The authors declare no conflicts of interest.

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