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An Improved Polyurethane using as Glass Fiber Reinforced Polymer Transmission Poles and Crossarms

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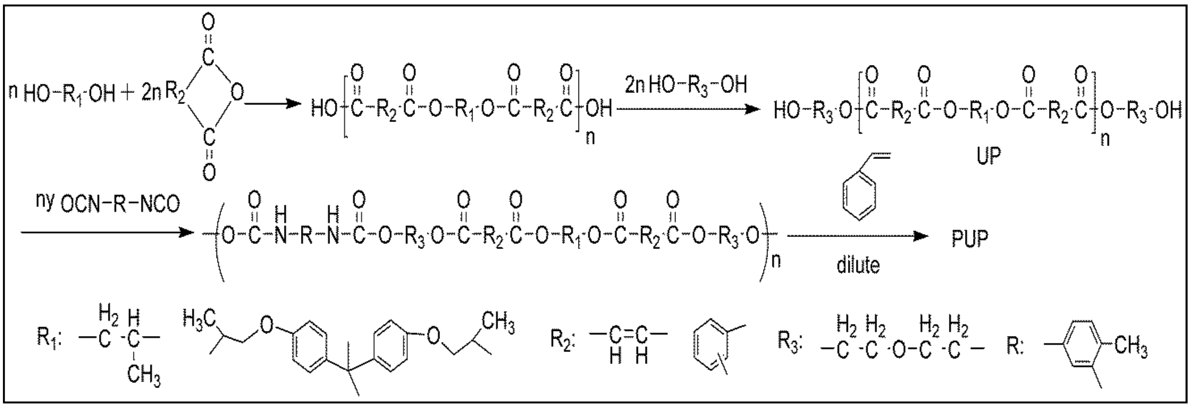
Abstract. By the design of molecular structure, improved polyurethane was synthesized and the material exhibited excellent mechanic properties, electrical insulation, resistance to chemical corrosion and UV aging. Its tensile and flexural strength were 58.4 MPa and 101.2 MPa; surface and volume resistivity were 9.68 × 1015 Ω and 2.60 × 1016 Ω.cm, respectively; and their loss modulus was less than 13% exposed under serious chemical substance and UV irradiation. Moreover, the properties of the polyurethane were superior to traditional epoxy and unsaturated polyester resin. Herin, resulted composite material poles and cross arms were operation under demonstration line, and accumulated relevant operating parameters.

1. Introduction

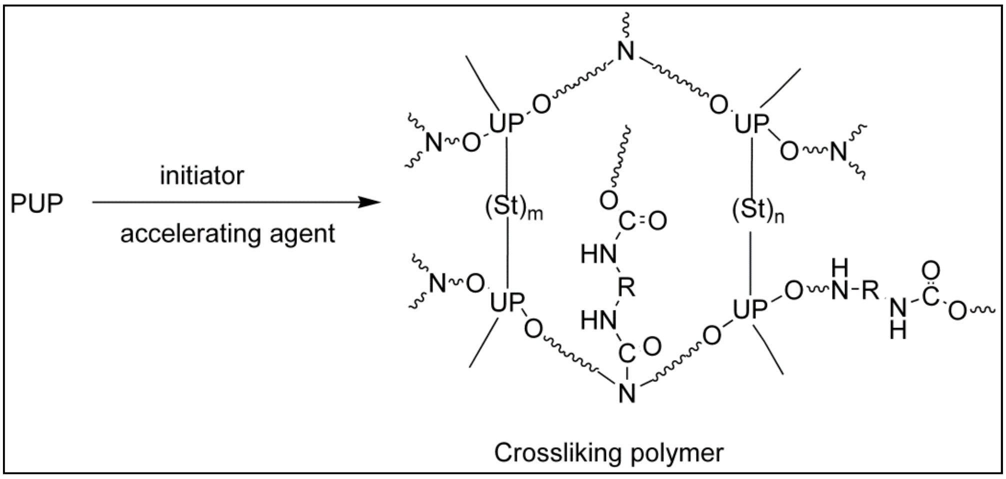
The polyurethane-based materials are remarked by their excellent mechanic properties and adhesion to glass, steel, wood and concrete, along with a good resistance to acid, base, UV and weather for their peculiar structures [1-5]; Due to the versatile synthesized methods and processing, polyurethane-based materials are now widely used as base material in various industries, particularly as electrical materials because of their outstanding electrical insulation [6-8].

2. synthesis of the polyurethane

Herein, a kind of polyurethane based on unsaturated polyesters (PUP) was prepared from dihydric alcohol, maleic anhydride, propoxylated bisphenol A, hexahydrophthalic anhydride and diphenylmethanediisocyanate, then diluted with crosslinking agent styrene (Scheme 1). PUP resin can be cured and undergo crosslinking reaction under room temperature with initiator and accelerator agent as scheme 2.



Scheme 1. Synthesis route of PUP resin.



Scheme 2. Curing reaction of PUP resin under room temperature.

3. Disscussion

Comparing to traditional epoxyl E51 and unsaturated polyester 196 (UP) thermosets, the resulting PUP-based polymer samples not just showed better mechanic properties (Table 1), but also along with higher insulation of electricity (Table 2). The tensile strength, flexural strength, and elongation at break of PUP samples were 58.4 MPa, 101.2MPa and 3.25%, tensile and flexural modulus were 3.15 GPa and 3.05 GPa, respectively, these were all superior to that of traditional E51 and UP materials. The dielectric loss factor was 4.96×10-3, lower than that of traditional E51 and UP materials; surface resistivity and volume resistivity were 6.68×1015Ω and 2.60×1016Ω.Cm, higher than that of E51 and UP materials. Moreover, the surface of cured PUP sample exhibited certain degree of hydrophobicity, the average hydrophobic angle of PUP samples' surface was about 94o, higher than that of UP and E51 samples, corresponding hydrophobic data and photographs can be seen in table 3.

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Table 1. Mechanic properties of PUP-based materials and E51, unsaturated polyester.

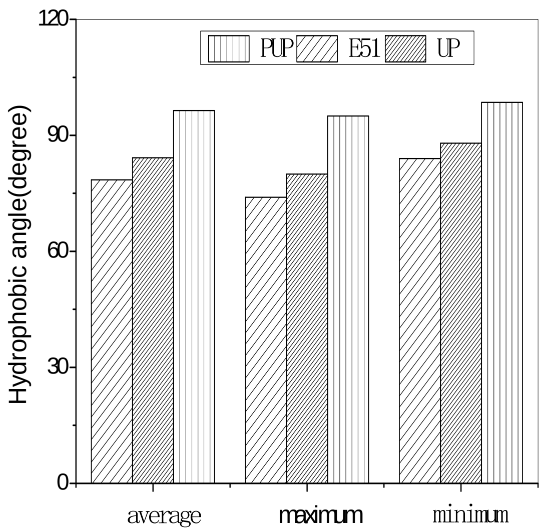
Samples	Tensile strength (MPa)	Elongation at break (%)	Tensile module(GPa)	Flexural strength (MPa)	Flexural module (GPa)
PUP	58.4	3.25	3.15	101.2	3.05
E51 expoyl	58.0	2.98	2.71	86.4	2.57
Unsaturated polyestes 196 (UP)	48.5	2.16	3.14	97.9	3.14

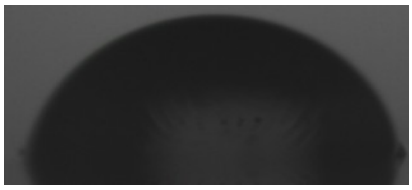
Table 2. Electrical insulation of the samples under room temperature.

Samples	Dielectric loss factor tanδ	Surface resistivity (Ω)	Volume resistivity (Ω.Cm)
PUP	4.96×10^{-3}	9.68×10^{15}	2.60×10^{16}
E51 epoxyl	4.99×10^{-3}	9.05×10^{15}	1.36×10^{16}
UP	7.44×10^{-3}	5.64×10^{15}	2.23×10^{15}

Considering the stability of PUP materials under atmosphere condition, the weather ability of PUP materials was also studied. As shown in table 4 and table 5, PUP based samples exhibited outstanding endurance to chemic solution and UV irradiation. After saturated in 5wt% HCl and 10wt% NaOH solution at 80^{o}C for two weeks, the remaining modules of PUP samples were respectively 93% and 87%, much higher than that of E51 and UP samples. Similarly, undergone UV irradiation for 28 days with the wavelength of 310 nm, the remaining modulus of PUP samples was 98.5%, also much higher than that of E51 and UP.

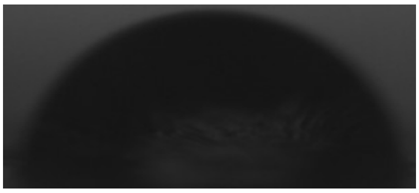
Table 3. Hydrophobic properties and hydrophobic angle photo.





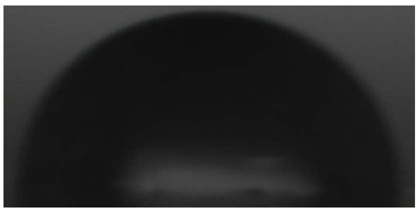
E51

87^o



UP

90^o



PUP

94^o

Table 4. Remaining modules of the samples saturated under chemic solution at 80^{o}C.

Samples	Chemic solution	7 days	14 days
PUP	5% HCl	93%	93%
	10% NaOH	92%	87%
E51 epoxyl	5% HCl	90%	81%
	10% NaOH	90%	80%
UP	5% HCl	79%	70%
	10% NaOH	68%	45%

Table 5. Remaining modules of the samples exposed under UV irradiation (0.71 W/m^2/nm)

Samples	7 days	14 days	21 days	28 days
PUP	99.5%	99.7%	99.1%	98.5%
E51 epoxyl	98.0%	95.6%	92.3%	89.1%
UP	98.4%	96.5%	91.2%	90.9%

Based on the PUP resin, we designed and manufactured fiber reinforced polymer (FRP) composite transmission poles and crossarms. As shown in Figure 1, 110kV single pole transimision tower and 220kV composited material truss tower were maded from PUP resin, the height of the composite pole were 32.5m, consisting with three sections of FRP composite pipes, which had been running in Jingchao transmission line in Xining citu (Qinhai provinxe) and Kuanfeng transmission line in Dangdong city, Liaoning province. Similarly, PUP FRP composite crossarm was also produced (Figure 1, right), and applicated in Hulunbeir, extremely cold area of Mengdong. It was used in 10kV distribution transmition line, about 1.0 m in length, which could improve the lightning impulse voltage and pollution surface discharge by 210% and 15% respectively, comparing to traditional metal crossarms.

Figure 1. NARI 110kV FRP composite pole (left) ,220kV truss tower(middle) and 10kV crossarms and poles (right) manufactured with PUP resin.

4. Conclusion

In summary, PUP resin showed excellent mechanic properties, electrical insulation and endurance to acid and base, UV irradiation. Based on the PUP resin, FRP composite poles and crossarms had be manufactured, and running in the transmission lines, to collect relating operation and maintenance experience of FRP composite poles and crossarms.

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