S.A. Awad
College of Education for Pure Science, University of Anbar, Ramadi, Iraq.
msc1981@gmail.com

E.M. Khalaf
College of Education for Pure Science, University of Anbar, Ramadi, Iraq.
emanmohammed467@yahoo.com

Improvement, the Performance of Polyurethane (PUR), Y-290 Resin as Coating of Oil Pipeline by Using Multi-Walled Carbon Nanotubes (MWCNTs)

Abstract- *In this study, polyurethane epoxy-Y290 (PUR-Y290) as a matrix material was reinforced by 1%MWCNTs. Polyurethane is a thermoset polymer and using for several applications particularly as coatings of gas and oil pipeline. Polyurethane uses as a liquid coating against the corrosion, and that is caused by the direct exposure for long periods of UV irradiation and humidity. The nanocomposites were prepared by adding 1wt% MWCNTs to polyurethane and mixed by using an ultrasound mixer. Polyueethane-1%MWCNTs composite sample was exposed to accelerate weathering (UV irradiation coming from sunlight, moisture, and salt water spray) during the exposure to different durations 6 months, 12 months and 24 months. Exposed and unexposed samples were investigated and evaluated by thermal and mechanical tests.It was found that the incorporation 1.0%wt of MWCNTs filler, enhanced the thermal stability and improved the mechanical properties during the exposure for long-term life to accelerated weathering conditions, compared with polyurethane coating without MWCNTs filler. These results indicated that polyurethane (liquid coating) nanocomposites have a higher resistance to environmental condition and give more protective against corrosion of oil pipelines and applied as coatings by spray method to protect the oil pipeline surfaces from environmental conditions.*

Keywords: *PUR-Y290, MWCNTs, Thermal stability, Tensile strength, corrosion, oil pipeline*

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1. Introduction

With the continuous development of the world economy and a high demand for the world markets for crude oil products and derivatives to reduce the increased demand for petroleum products. Several methods are used to protect crude oil pipelines from corrosion due to harsh environmental conditions such as the effects of intense sunlight (UV radiation) and high humidity and rain, which affect their efficiency and cause damage to the oil pipeline [1-3]. Since 1950, the construction of oil pipelines was designed according to the standards less than the current time. In the past, Oil pipelines were suffering from damage due to storms and environmental fluctuations or because of the lack of equipment and maintenance programs to deal with these losses, but at present and with progress in technology and materials performance efficiency, many ways have emerged to protect oil pipelines [4-6]. Corrosion poses a threat to all infrastructure and the economic influence of all types of corrosion and its degradation of infrastructures, such as pipelines, oil rigs, and towers, offers an annual cost of many millions of dollars to the industrial sector [7-8]. Polyurethane (PUR) composites have become an accepted alternative in the infrastructure industry, in particular for applications requiring high strength-to-weight ratios and durability [9-12]. PU systems are a low-cost, high-performance polymer. with durability contributes significantly to the long lifetime of many products [13]. This longevity of PU products life cycle leads to resource conservation, important environmental considerations that often favor the selection of polyurethanes. Another significant factor in the success of polyurethane is the ability to produce PU in various forms, from flexible, easily deformed to rigid load bearing materials. Polyurethanes with multi-walled carbon nanotubes (MWCNTs) fillers have achieved widespread applications in foams and paints, coatings, structural materials and composites such

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

as MWCNTs and nano inorganic material due to their excellent abrasion resistance, toughness, strength, cost benefits and potential environmental reliability [14-15]. In this work, UV irradiation effects on polyurethane and polyurethane-1% MWCNTs are investigated by using UV light sources with 340nm wavelengths for various durations and evaluated before and during to UV irradiation to develop high resistance nanocomposite coating (PUR-1%MWCNTs) aginst environmental conditions that are caused the corrosion of oil pipelines.

2. Experimental Work

I. Materials and Methods:

Polyurethane-Y290 was provided from Sika Ltd Company under the commercial name (Sikaflex), USA. Multi-walled Carbon Nanotubes (MWCNTs) was purchased from AD Nano Technologies, UK.

II. Composite preparations

Neat PUR-Y290 was stirred using a high-speed mixer to lower the viscosity before adding 1%MWCNTs. The mixture was applied to a high shear rate of 5000 rpm for 2 hours at room temperature. Then, the mixture was sonicated for 5 hours to further disperse with MWCNTs. After that, the mixture was poured into Aluminum molds that have the dimensions (100mm length, 50 mm width, and 2.5mm thickness) and left to cure for 7 days at room temperature.

III. Accelerated weathering tests

Neat PUR-Y290 and PUR-Y290-1%MWCNTs composite samples of each type of coating were placed vertically to accelerated weathering for 24months as a maximum limit in an accelerated weatherometer with a UVA-290nm† lamp. The specimens were subjected to attack by degrading basics of the weather, particularly UV light, moisture and salt water (40±5°C). Continuing a cycle of 8 months UV and 8 months condensations, and also after 8 months of the salt water of a total maximum exposure (24 months) according to the standard tests (ASTM B117) [16]. After 6, 12, 24 months exposure time, the samples were carried out and analyzed by the mechanical and thermal tests.

IV. Tensile Strength Tests

Tensile strength was performed by a universal testing machine The specimens were tested according to ASTM D638 using the dog-bone shape of all samples with dimensions (100 mm length, 25 mm width, and 2.5 mm thickness). The testing speed was 5 mm/min. Specimens were positioned vertically between the grips of the testing machine, and stress-strain curves were plotted during the test.

V. Gravimetric analyses, TGA

Thermogravimetric Instrument (Perkin-Elmer) company was used to follow the thermal stability of pure PUR and PUR nanocomposites. The rate of heating of samples was about 10 ^{o}C min^{-1} in the range 20-600 °C, and the weight of the sample was in the range between 5-10mg. The loss of mass was followed in response to increasing the temperature of both pure PUR-Y290 and PUR-Y290- MWCNTs composites.

3. Results and Discussion

I. Tensile tests

The tensile stress-strain curves are displayed in Figure 2 and Table 1. It is observed that tensile strength and modulus of PUR-Y290-MWCNTs composites were increased to (52.4±2.6MPa) with the incorporation of 1% MWCNTs content, but no significant decreasing occurred after 24 months (52.5±4.3) exposure to accelerated weathering. Neat PUR-Y290 increased from (46.4±1.2)MPa before exposure to (27.7±0.9 MPa) after exposure. Table 2 shows that modulus of elasticity increased to (320±5.8MPa), but there is more resistance of decreasing of elasticity (307±3.8 MPa) after exposure, compared with neat PUR-Y290 that dropped from 127±4.6 MPa before exposure to (35.5±2.2MPa) that didn't appear significant improvements. The results of strain at break is shown in Table 2. It is indicated that a higher value of strain at break was (5.4 ± 0.5%) of PUR-Y290 before exposure and this value was increased to (11.1±1.4%) after exposure to 24-month artificial weathering, compared with strain at break values of PUR-Y290-1%MWCNTs composite that were (1.2±0.5%) before exposure and (1.9±0.7) after exposure to 24-month artificial weathering.These improvements refer to the high crosslinking between epoxy adhesives(PUR-290) and the additive material (MWCNTs) that reduced the

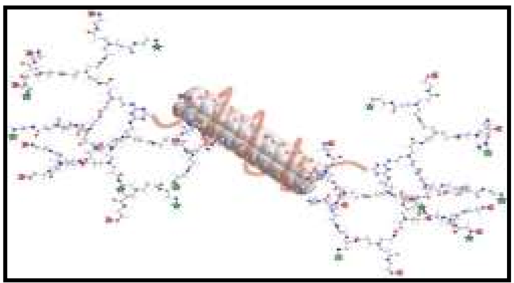

Figure 1: PUR-MWCNTs composites

excessive brittleness [17].

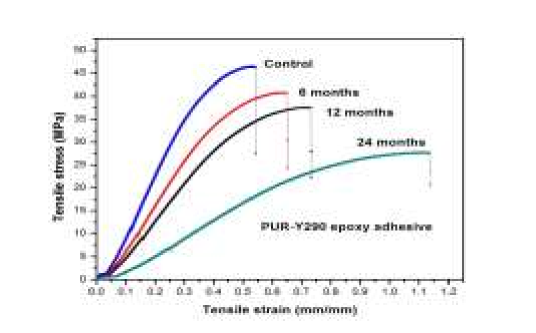

Figure 2: Tensile Stress-Strain curves of PUR specimens before accelerated weathering (BAW) and after different times of accelerated weathering

Table 1: Tensile tests of neat PUR and PUR-1%MWCNTs composite before and after different accelerated weathering times

Exposure condition	Tensile strength (MPa)	Modulus of Elasticity (MPa)	Strain at break (%)
PUR-Y290	46.4 ± 1.2	127 ± 4.6	5.4 ± 0.5
6months	41.1 ± 0.9	103.3 ± 3.7	6.4 ± 0.6
12months	37.2 ± 0.7	70.3 ± 2.4	7.4 ± 0.3
24months	27.7 ± 0.9	35.5 ± 2.2	11.1 ± 1.4
PUR-Y290-1%MWCNTs	52.4±6.2	320 ± 5.8	1.2 ± 0.5
6months	52.5 ± 4.3	314 ± 7.6	1.5 ± 0.2
12months	48.2 ± 3.7	310 ± 4.3	1.8 ± 0.4
24months	45.4 ± 3.2	307 ± 3.8	1.9 ± 0.7

Table 2: The results of strain at break

Sample exposure	Initial temperature (T_i)	Maximum temperature (T_{max})	Residual yield %
PUR-Y290	370.5	390.6	14.5
24months	350.0	365.5	11.6
PUR-Y290-1%MWCNTs	460.0	470.0	18.0
24months	455.0	464.7	17.5

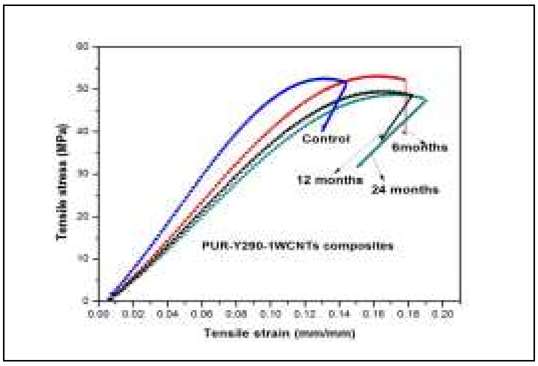

Figure 3: Tensile Stress-Strain curves of PUR-MWCNTs composite specimens before accelerated weathering (BAW) and after different times of accelerated weathering

II. Thermal degradation analysis of PUR nanocomposites

Thermal degradation behavior of the PUR –Y290 pure and MWCNTs samples before exposure and after exposure are shown in Figure 4, and T_i referring to the initial degradation temperature and relevant factors on thermal stability. At maximum degradation temperature (T_{max}.). Figure 4, it was stated that the thermal decomposition of samples was decreased with the increasing of exposure to UV and humidity. However, PUR-Y290-1%MWCNTs composites had higher resistance to accelerated weathering. The incorporate of the MWCNTs nanoparticle allowed higher stability of PUR matrix and gave good interfacial adhesion between MWCNTs nanoparticle and the neat PUR-Y290. Table 2 shows T_i, T_{max}, and residual yield of neat PUR and PUR-Y290 -1% MWCNTs composite. The rising in the thermal stability of the PUR-1%MWCNTs nanocomposite was higher compared with neat PUR. From Table 2, T_{max} of neat PUR was (390.6ºC) while for PUR-Y290 -1% MWCNTs nanoparticle composite was about (549.5ºC). Residual yield showed the highest amount of PUR-Y290-1%MWCNTs nanoparticle (18%) and (17.5%) after exposure to 24 months that indicated to the maximum resistance to thermal decomposition.On the other hand, the residual yield of the neat PUR was (14.5%) before exposure and (11.6%) after exposure to 24 months as shown in the Table 2. The values in Table 2 demonstrate that MWCNTs nanoparticle fillers were enhanced by the high protecting effect the thermal decomposition and improved the thermal stability of neat PUR-Y290. These indicate that the degree of crosslinking of MWCNTs nanoparticles is higher than the bond break of neat PUR-Y290 [18]. In the maximum stage, the mass loss of PUR-Y290-1%MWCNTs nanoparticle composites is less than the weight loss of neat PUR-Y290.

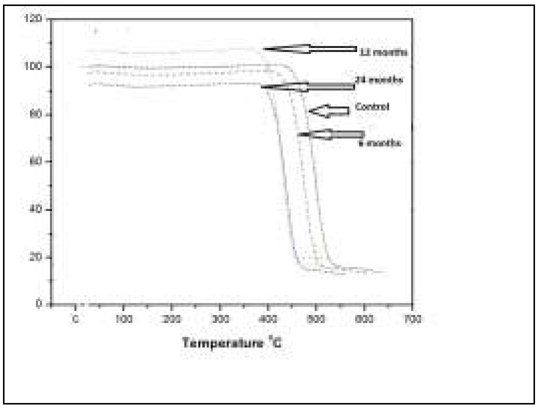

Figure 4: TGA Thermograms curves of Neat PUR and PUR-1%MWCNTs specimens before accelerated weathering (BAW) and after different times of accelerated weathering (AAW)

4. Conclusion

1. Incorporation 1% MWCNTs improved the mechanical resistance of PUR-Y290 against the environmental weathering conditions by 50% after exposure to 24 months.
2. PUR-Y290-1%MWCNTs composite has enhanced the thermal stability and inhibited a thermal degradation after exposure to artificial environmental weathering, compared with thermal degradation of neat PUR-Y290 that was increased after exposure to 24-month artificial weathering.
3. MWCNTs fillers demonstrated have a high inhibition against the corrosion and environmental impacts when are mixed with epoxy adhesives (PUR-Y290) as a liquid coating of an oil pipeline.

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Author(s) biography

Sameer A. Awad is lecturer at University of Anbar, College of Education for Pure Science since 2008. He has M.Sc. in Chemical Science from College of Science. His research interests are polymer composites, polymer materials and the applications in science and engineering fields. I have several publications and participations in local and international.

Eman M. Khalaf has M.Sc. in chemical science from College of Education for Pure Science 2014. She published several papers in international conferences and Journals.