Essentium PCTG Saltwater Evaluation

Materials R&D Team – Essentium Inc. 12/22/2021

Background

Essentium PCTG is an easy-to-print, tough material with moderate chemical resistance. No data from the resin manufacturer was available regarding saltwater resistance. Therefore, Essentium conducted a study based on 1000 hours of immersion in artificial seawater (ASW). For this study, multiple ISO 527 tensile specimens were produced on the Essentium HSE 180 HT printer with the print direction oriented along the testing axis of the specimens. The specimens were divided in three groups: control in standard air, submerged in ASW, and submerged in tap water. The test procedure followed the guidelines of the ISO 175:2010(E) standard.

Test Preparation

Eighteen clear PCTG tensile specimens were printed from dry PCTG filament (less than 400 ppm) on an Essentium HSE with the following print settings:

- Hozzle Temperature 310 °C
- Bed Temperature 80 °C
- IR 1 & 2 0 °C
- Print Speed 150 mm/s
- Extrusion Ratio 1
- K Factor 0.1

Once the samples were printed and numbered, weights were taken with a Brookfield analytical balance. Three measurements each of width and thickness of the gauge section were taken with a Mitutoyo micrometer. Appendix A gives the weights and measurements. Measurements pre and post conditioning in water may vary slightly due to locations being un-marked on the samples.

Two 1-gallon wide mouth jars were cleansed and wiped out prior to filling with ASW and tap water to a marked level. Small binder clips were used to resist the buoyancy of the samples and keep them submerged.

Samples were labeled and placed in their designated conditioning environment: 1-6 in ASW, 7-13 in tap water, 14-19 in air in the laboratory. All were conditioned at 23 ± 2 °C for 1000 hours. ASW was made with Instant Ocean Sea Salt™ in the manufacturer suggested ratio of ½ cup to 128 Oz. of tap water, mixed and stirred and left overnight in order to reach equilibrium.

Water was stirred weekly, and volume was monitored for loss. No water evaporated below the samples; a small amount of rust was deposited onto the samples from binder clips by the end of the experiment as seen in Figure 1.

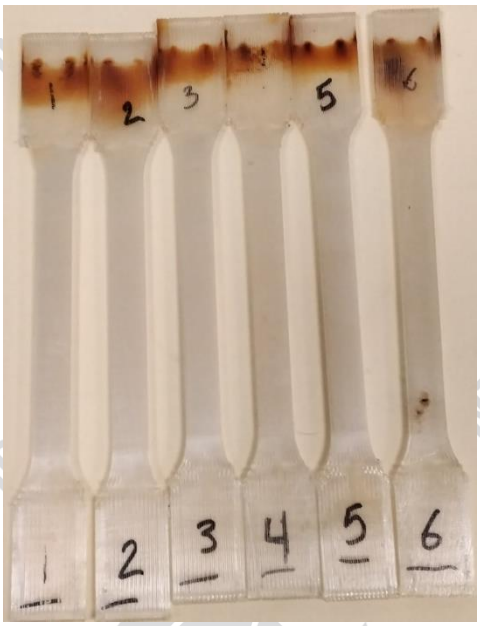

Figure 1. Rust deposited on the specimen tabs during seawater treatment, but it did not affect the test section.

Results

There was no significant visual difference between ASW, freshwater and air samples aside from the deposition of iron oxide from the binder clips.

PCTG absorbed some ASW with a mass increase of 1.3%, and PCTG in freshwater absorbed 1.4%, as seen in Appendix A. For equilibrium samples, no change was noted.

The specimens were then tested on an Instron universal test frame with 5 kN load cell. Specimens were pulled at 1 mm/s from 0% to 0.25% strain, then at 5 mm/s until failure, according to the guidelines of ISO 527.

Table 1. Summary results including average and (standard deviation) for 6 ISO 527 specimens tested in each condition.

	Tensile Yield Stress [MPa]	Strain at Yield [mm/mm]	Tensile Modulus [GPa]	Strain at Break [mm/mm]
Artificial Seawater	48.4 (0.55)	4.3% (0.2%)	1.86 (0.03)	174% (19%)
Freshwater	48.9 (0.65)	4.5% (0.0%)	1.87 (0.05)	149% (40%)
Air	52.2 (0.85)	4.5% (0.3%)	1.93 (0.04)	26.8% (21%)

The yield stress for PCTG was reduced by 3.8 and 3.3 MPa, respectively, for ASW and freshwater treated specimens, compared to the control sample that was conditioned in air. Likewise, there was a reduction in the tensile modulus of about 3.6%, or 0.07 GPa, for ASW samples and a similar 0.06 GPa for freshwater samples. The strain at break was markedly improved after water treatment, with immersed samples averaging about 150% elongation at break or more. Curves for the ASW are given below in Figure 2.

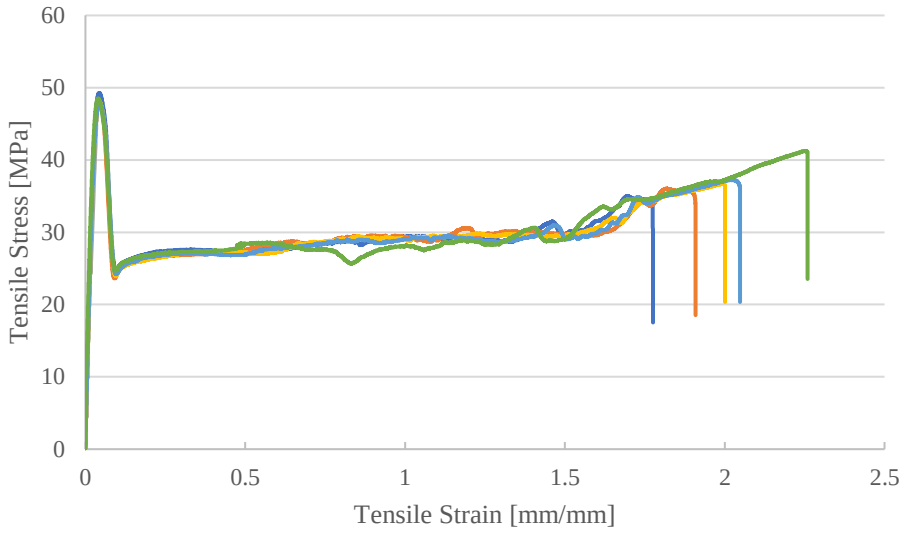

Figure 2. Tensile test results for ASW-treated PCTG specimens showed exceptional elongation.

These mechanical results, combined with the 1.3% increase in mass, suggest that water was absorbed which improved ductility and slightly lowered the tensile modulus.

Conclusion

Treatment of PCTG in artificial seawater or freshwater for 1000 hours did not significantly affect the mechanical properties of PCTG. The tensile yield stress was reduced by 7.3% and the tensile modulus was reduced by 3.6%, but these changes should not lead to noticeable performance differences. The elongation at break was greatly improved, which is consistent with the moisture uptake measured in the mass and with historical results obtained at Essentium for specimens conditioned in humid air.

Appendix A – Sample Dimensions

	Pre-Condition Sample #	Width			Thickness			Weights	
		Gauge 1	Gauge 2	Gauge 3	Gauge 1	Gauge 2	Gauge 3		
ASW Pre-Conditioning	1	10.04	9.98	10.01	3.99	4.00	4.01	11.49	**Avg. Width (mm)**
	2	10.02	9.99	10.03	4.03	3.99	3.99	11.50	10.01
	3	10.01	9.98	10.02	4.01	3.98	3.98	11.48	**Average Thickness (mm)**
	4	10.04	10.00	10.04	4.03	4.01	4.03	11.58	4.00
	5	10.01	9.96	10.01	4.02	3.99	3.99	11.48	**Avg. weight (g)**
	6	10.06	10.01	10.02	4.00	3.97	4.03	11.51	11.51
Tap Water Pre-Conditioning	7	10.05	9.99	10.01	4.01	3.99	4.02	11.49	**Avg. Width (mm)**
	8	9.99	10.00	10.02	4.02	4.00	4.01	11.54	10.05
	9	10.22	10.37	10.15	4.08	4.05	4.08	11.64	**Average Thickness (mm)**
	10	10.03	9.98	10.00	4.01	4.00	4.03	11.54	4.02
	11	10.07	10.06	10.02	4.01	3.97	4.02	11.54	**Avg. weight (g)**
	12	9.99	9.97	10.02	4.02	4.00	4.00	11.47	11.53
Air Pre-Conditioning	13	9.99	9.97	9.99	4.03	3.99	4.02	11.49	**Avg. Width (mm)**
	14	10.05	10.04	10.07	4.02	4.00	4.01	11.51	10.03
	15	10.03	9.99	10.06	4.03	4.00	4.02	11.55	**Average Thickness (mm)**
	16	10.03	10.01	10.04	4.04	4.02	4.02	11.54	4.02
	17	10.04	10.00	10.08	4.02	4.01	4.03	11.57	**Avg. weight (g)**
	18	10.02	10.02	10.07	4.02	4.00	4.01	11.59	11.54
		Width Avg.(mm)-		10.03	**Thickness Avg.(mm)-**		4.01	11.53	

Appendix A – Sample Dimensions

	Post Conditioning	Width			Thickness				
	Sample #	**Gauge 1**	**Gauge 2**	**Gauge 3**	**Gauge 1**	**Gauge 2**	**Gauge 3**	**Weights**	
ASW Post-Conditioning	1	10.06	9.99	10.05	4.01	4.02	4.05	11.64	**Avg. Width (mm)**
	2	10.35	9.98	10.02	4.02	4.00	4.05	11.66	10.04
	3	10.05	9.99	10.04	4.00	4.02	4.00	11.62	**Average Thickness (mm)**
	4	10.05	10.02	10.06	4.05	4.02	4.05	11.73	4.02
	5	10.03	9.98	10.02	4.05	4.03	4.00	11.63	Avg. weight (g)
	6	10.03	10.03	10.03	4.03	4.00	4.03	11.69	11.66
Tap Water Post-Conditioning	7	10.00	9.99	10.04	4.00	4.00	4.03	11.64	**Avg. Width (mm)**
	8	10.10	10.00	9.99	4.03	3.99	4.00	11.67	10.03
	9	10.18	10.07	10.03	4.08	4.04	4.07	11.80	**Average Thickness (mm)**
	10	10.01	10.00	10.02	4.02	4.00	4.02	11.71	4.01
	11	10.04	10.05	10.04	4.00	3.98	4.01	11.68	**Avg. weight (g)**
	12	10.02	9.91	10.01	4.00	4.00	4.01	11.65	11.69
Air Post-Conditioning	13	9.99	9.97	9.99	4.03	3.99	4.02	11.49	**Avg. Width (mm)**
	14	10.05	10.04	10.07	4.02	4.00	4.01	11.51	10.03
	15	10.03	9.99	10.06	4.03	4.00	4.02	11.55	**Average Thickness (mm)**
	16	10.03	10.01	10.04	4.04	4.02	4.02	11.54	4.02
	17	10.04	10.00	10.08	4.02	4.01	4.03	11.57	**Avg. weight (g)**
	18	10.02	10.02	10.07	4.02	4.00	4.01	11.59	11.54