



Moisture Absorption: Thermoplastic Composites

As moisture is absorbed into a polymer composite it has a plasticizing effect on the material. This results in a degradation in the strength of the composite. The amount of moisture absorbed is inversely proportional to the strength. In addition, absorption of moisture means increased weight. While weight gain may not even be noticeable on a very small structure it is quite noticeable on large structures where a percent or two of moisture uptake can add many pounds. Table 1 shows various thermoplastics and their moisture absorption rates based upon the ASTM D570 test procedure. Most thermoplastics have excellent resistance to moisture; however, several of the nylon polymers (PA6 & PA66) absorb 20 times more moisture than other thermoplastics. Structures that are exposed to high moisture environments should avoid these nylon polymers.



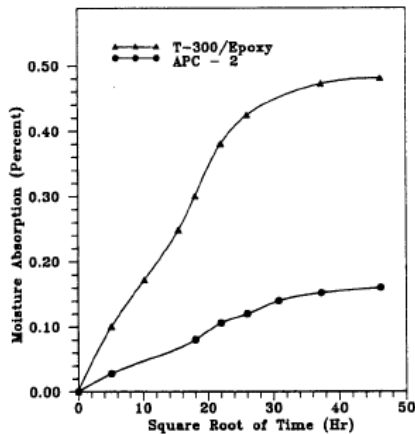
Table 1: Relative Comparisons of Moisture Absorption in Thermoplastics

Polymer	Tensile Strength (Mpa)	Modulus (Gpa)	Service Temp (C) (Long Term)	Moisture Absorption %(24h)	Ref
PE	18/35	0.7/1.4	70/80	<0.01	1
PP	21/37	1.1/1.3	100	<0.03	1
PA6	70/85	1.4	80/100	1.3/1.9	1
PA66	77/84	2	10/120	1.5	1
PA11	56	1	70/80	0.3	1
PA12	56/65	1.6	70/80	0.25	1
PC	56/65	2.1/2.4	135	0.16	1
PET	47	3.1	100	0.3	1
PBT	40	2	100	0.08	1
PPS	90	3.8	225	0.01	4
PEEK	100	3.6	250	0.1	5
PEI	105	3	300	0.25	3
PEKK	89	3.4	215	<0.2	2

Compared to thermosetting epoxy resins, thermoplastic resins offer superior moisture resistance (Ref 6). Moisture absorption coupled with elevated temperature can have a compounding effect on strength. Figure 1 and Table 2 highlight a comparison of PEEK (APC-2) and an epoxy resin. Figure 1 displays that the moisture pick-up over a 90 day period which results in only 0.16% for PEEK and increases to 0.48% for the epoxy. This is a 3x weight increase for the epoxy as compared to thermoplastics. The resulting effect on strength is shown in Table 2. Compared to ambient/dry conditions the PEEK degrades in strength by only 18%, whereas the epoxy degrades by 25% at 100°C.



Figure 1: Moisture Absorption Comparing PEEK (APC-2) and Cycom 985 Epoxy. (Ref 6)



Conditioning	APC-2		Graphite/Epoxy		
	Comp. Ult. Ksi (MPa)	Comp. Mod. Msi (GPa)	Comp. Ult. Ksi (MPa)	Comp. Mod. Msi (GPa)	
23°C	D	93.74 (637.43)	1.26 (8.68)	92.17 (635.41)	1.10 (7.58)
	M	84.99 (585.92)	1.27 (8.75)	83.58 (576.20)	1.05 (7.23)
80°C	D	87.62 (604.05)	1.21 (8.34)	77.27 (532.69)	1.08 (7.44)
	M	83.65 (576.68)	1.17 (8.06)	74.55 (513.94)	0.92 (6.34)
100°C	D	77.30 (532.90)	1.05 (7.23)	76.26 (525.73)	0.88 (6.06)
	M	76.68 (528.63)	1.11 (7.65)	69.39 (478.37)	0.86 (5.92)

D—dry.
M—90 days moisture exposure.

Table 2: Moisture & Temperature Influence on Compressive Properties of PEEK vs. Epoxy. (Ref 6)

Two of the highest strength advanced thermoplastics are PEEK and PEKK. Reference 7 gives a comparison between these two systems. Figure 2 highlights PEEK as having slightly better moisture resistance. Figure 3 illustrates the effect of moisture and temperature on open hole compression strength. It is obvious that the main contributor to strength reduction is temperature and not so much moisture, as the strength difference between 82°C/Dry and 82°C/Wet are only a percent or so.

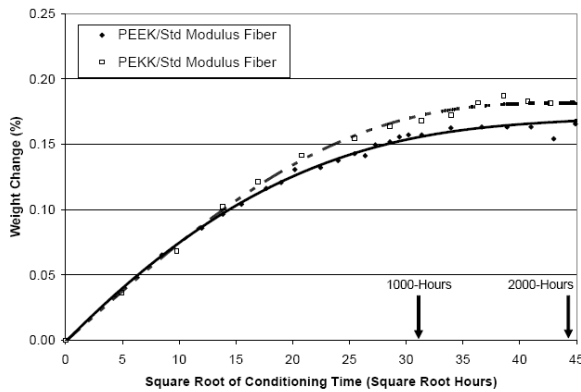


Figure 2: Weight Change of PEEK and PEKK Standard Modulus Carbon Fiber Composites Conditioned at 70°C and 85% Relative Humidity. 32-Ply Quasi-isotropic Laminates. (Ref 7)

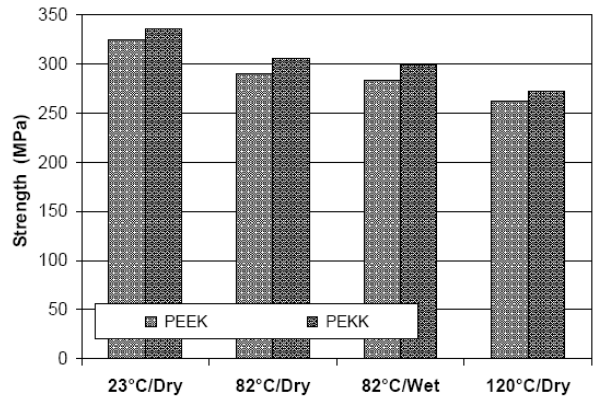


Figure 3: Effect of Temperature and Humidity on Open-Hole Compressive Strength, Unidirectional Tape with Standard Modulus Carbon Fiber. Quasi-isotropic Laminates. (Ref 7)

Ref 1 "Organic Sheet Process Chain", Institut Fur Verbundwerkstoffe, Nov 2003

Ref 2 Material Data Sheet, "OXPEKK-SP", Oxford Performance Materials, Inc.

Ref 3 Material Data Sheet, "Ultem 1000", SABIC Innovative Plastics

Ref 4 Material Data Sheet, "Techtron PPS, unfilled", Quadrant

Ref 5 Material Data Sheet, "Ketrion UHP320, unfilled", Quadrant

Ref 6 Jia-Mo Bai and David Leach, "High Performance Thermoplastic Polymers and Composites", SAMPE ISSE 2005

Ref 7 A. Haque and S. Jeelani, "Environmental Effects on the Compressive Properties: Thermosetting vs. Thermoplastic Composites" *Journal of Reinforced Plastics and Composites* 1992

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