

Understanding Creep in Composites: Thermoplastics

Creep can be defined as, “the continuous deformation of a material that is being subjected to a constant load.” Almost all materials can exhibit creep to some degree. The dominant factors influencing the level of creep in a composite material include:

1. **Sustained Load:** The closer the load is to the static failure load the higher the creep.
2. **Moisture Content:** Higher moisture content have a plasticizing effect resulting in higher creep.
3. **Temperature:** High temperatures, around or above the T_g , plasticize the matrix.
4. **Fiber Orientation:** Loads in matrix dominated directions are not reacted by the creep limited effects of the fibers.
5. **Fiber Content:** Amount of fiber vs. matrix material
6. **Flaws:** Internal flaws like voids increase creep.
7. **Fiber-Matrix Interface:** The degree of adhesion between the fiber and the matrix will cause more creep if the interface strength is low.
8. **Crystallinity:** The level of molecular alignment in a thermoplastic.

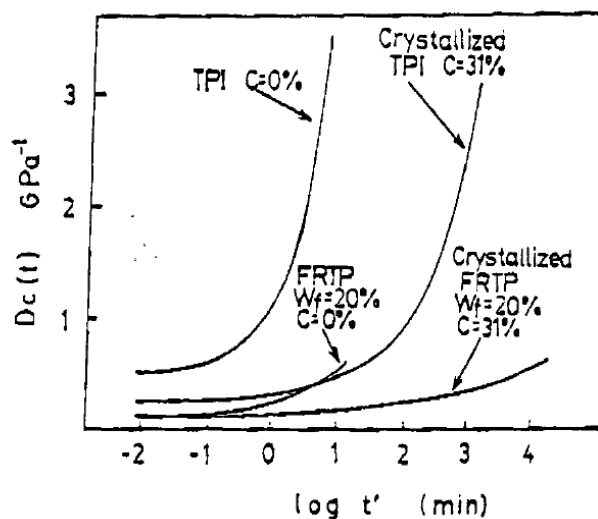


Figure 1: Creep compliance comparison at 0% and 31% crystallinity. Temperature = 240°C. TPI = unfilled polymer.

The effect is that more crystallinity yields better creep resistance. Both PPS and PEEK have high levels of crystallinity.

Of the thermoplastic matrices, two stand out as the most creep resistant: Polyphenylene Sulfide (PPS) and Polyetheretherketone (PEEK). The two main reasons for this are their high service temperatures, 225°C and 250°C respectively, and their level of crystallinity. Thermoplastics can be either amorphous or semi-crystalline. The long molecular chains are either randomly arranged (amorphous) or are somewhat regularly arranged and packed (semi-crystalline). Figure 1 (ref 1) shows creep compliance versus time for a 20% carbon fiber filled Polyimide thermoplastic, and compares the level of crystallinity. **The effect is that more crystallinity yields better creep resistance. Both PPS and PEEK have high levels of crystallinity.**

Figure 2 (ref 2) displays tensile strain vs. time for a 30% carbon fiber filled PEEK (CF/PEEK) at a temperature of 150°C. The static tensile strength for this material at 150C is 100 MPa. Figure 3 (ref 2) gives tensile strain vs. time for a unfilled PEEK at a temperature of 150°C. The static tensile strength for this material at 150C is 45 MPa. If the 20 MPa curve (20% of ultimate) on Figure 2 is compared to the 5 MPa curve (11 % of ultimate) on Figure 3 we can see the effect fiber fill has on creep. Essentially, the creep rate (strain/time) is 0.000408 %/hr and 0.00315 %/hr for the CF/PEEK and unfilled materials respectively. **This represents a 770% decrease in the creep strain rate for the CF/PEEK.**

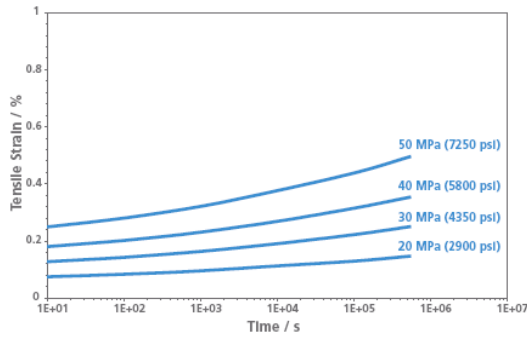


Figure 2: Strain vs. Time for 450CA30 CF/PEEK
Temp=150°C, Random Short CF, 30% by wt.

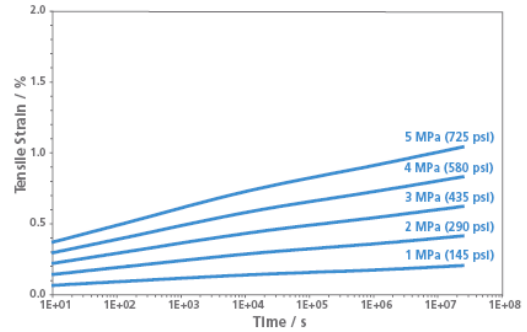


Figure 3: Strain vs. Time for 450G PEEK
Temp=150°C, Unfilled

Figure 4 (ref 3) plots the tensile strain vs. time for a 40% glass fiber filled PPS at a temperature of 150°C. The static tensile strength for this material at 150°C is 65 MPa. The strain rate for the 10 MPa (15% of ultimate) curve is 0.000142 %/hr. **This is a creep rate improvement of 287% over the CF/PEEK material.** Since the “fiber volume” (not fiber weight) of CF/PEEK and the glass filled PPS are almost the same, this says that PPS is better at resisting creep than PEEK.

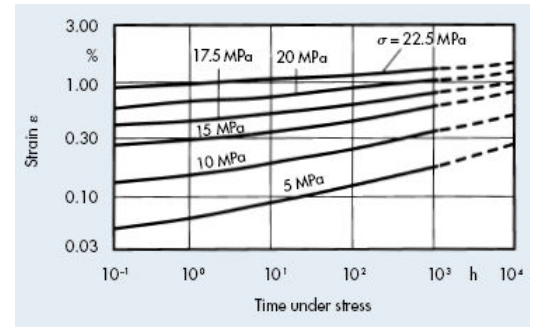


Figure 4: Strain vs. Time for 1140L4 PPS
Temp=150°C, Random Short glass, 40% by wt.

Figure 5 (ref 4) compares retention of dimensions (compressive strain) for compressive creep of 1140L4 PPS and a phenolic thermoset at two different temperatures (93°C & 150°C). Thermoplastic composites

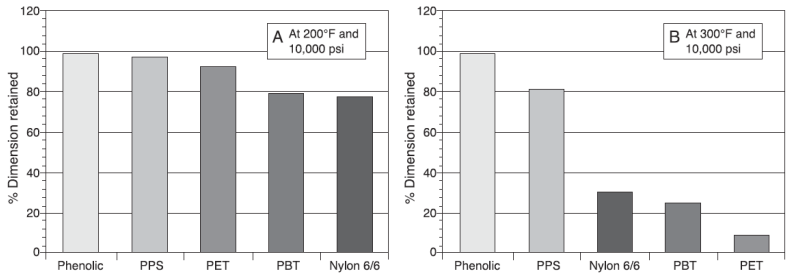


Figure 5: Compression Creep vs. Polymer Type

compete well with thermosets at lower temperatures, but will show more degradation at high temperature. If fiber is continuous and oriented, rather than short random fibers like that in 1140L4 PPS, then compressive and tensile creep can be reduced to near zero per reference 5.

In general, creep in thermoplastic composites can be minimized by:

1. **Putting fiber in the direction of load.**
2. **Lowering the operating temperature.**
3. **Decreasing the stress.**

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