Creep

Creep is the tendency of a polymer to distort under external loads, especially as the temperature increases.[1] Essentially, the polymer chains are uncoiling and begin to slip past each other when a constant stress is applied. This phenomena is temperature dependant since increased temperatures will decrease secondary bonding and increase chain mobility.

Crystalline polymers, with their high degree of secondary bonding, typically have a greater creep resistance than amorphous polymers. Polymers with large pendant groups, hence more chain entanglement, also tend to have a higher degree of creep resistance. Similarly, glass fibers in the plastic part will increase entanglement and decrease creep. Cross-linking and backbone chain stiffness also contribute to reduced creep.

Products can fail as a result of creep. Failure can occur due to the product elongating to the point where it slips out of position, or the product can elongate to the point where it breaks. This failure is termed *creep rupture* and can be useful in determining allowable stress limits in plastic components. Another thing to note is these failures can occur at stresses far below their yield strengths!

Due to this risk, test methods have been developed to quantify creep. These tests, such as ASTM D 2990 - 95 and ISO 899 – 1, specify the temperature, moisture level and time a material will be tested at. The results are graphically reported as MPa vs. time (h). The data may be represented as *isochronous* or *isometric* creep curves. An isochronous plot is generated by cutting sections through the creep curves at constant time intervals and plotting the stress as a function of strain.[2] Isometric plots of creep data are generated by taking constant strain sections of the creep curves and plotting the stress as a function of time.

Let's look at an example of how creep can affect part performance and how to calculate its effect.

Given:

Material:	PA66 (Nylon 6,6) vs. PA66 30%GF (Glass Filled)
Length:	$L = 500\ mm$
Diameter:	$d = 16\ mm$
Force:	$F = 3\,kN$
Temperature:	$T_{mzx} = 60\ ^\circ F$
Duration:	$t = 1000\ h$

Find:

From the figure and given information above, determine the amount of stress in the rod has and compare the strain results (creep) for both PA66 and PA66 30% glass filled.

Solution:

Calculate the area of the rod:

$$A = \pi \cdot r^2$$
$$\Rightarrow A = \pi \cdot (8mm)^2 \cong 201\ mm^2 = 201\ E-6 m^2$$

Calculate the stress in the *x* direction:

$$\sigma_x = \frac{F}{A}$$
$$\Rightarrow \sigma_x = \frac{3E3N}{201\ E-6m^2} \cong 14.9E6\ N/m^2 = 14.9MPa$$

If $\sigma_x < S_y$, then one can apply Hooke's Law.

Using the figures from the reference[2] listed below, we can determine the strain for PA66.

$$\varepsilon_{x,t} = \varepsilon_{x,1000} = 2.7\%$$ --- (no glass)

$$\varepsilon_{x,t,GF} = \varepsilon_{x,1000,GF} = 0.67\%$$ --- (30% GF)

Since Hooke's law applies, we have:

$$\frac{\Delta L}{L} = \varepsilon$$
$$\Rightarrow \Delta L = \varepsilon \cdot L = (0.027)(500\ mm) = 13.5mm$$ --- (no glass)

$$\Rightarrow \Delta L = \varepsilon \cdot L = (0.0067)(500\ mm) = 3.35\ mm$$ --- (30% GF)

Conclusion:

Glass filled nylon 6,6 will have creep less than unfilled nylon 6,6. Hence, glass mitigates the effect of creep in nylon 6,6.

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[1] Strong, A. Brent, *Plastics: Materials and Processing*, Prentice Hall, 2000.
[2] Osswald, et al, *International Plastics Handbook*, Hanser, 2006.