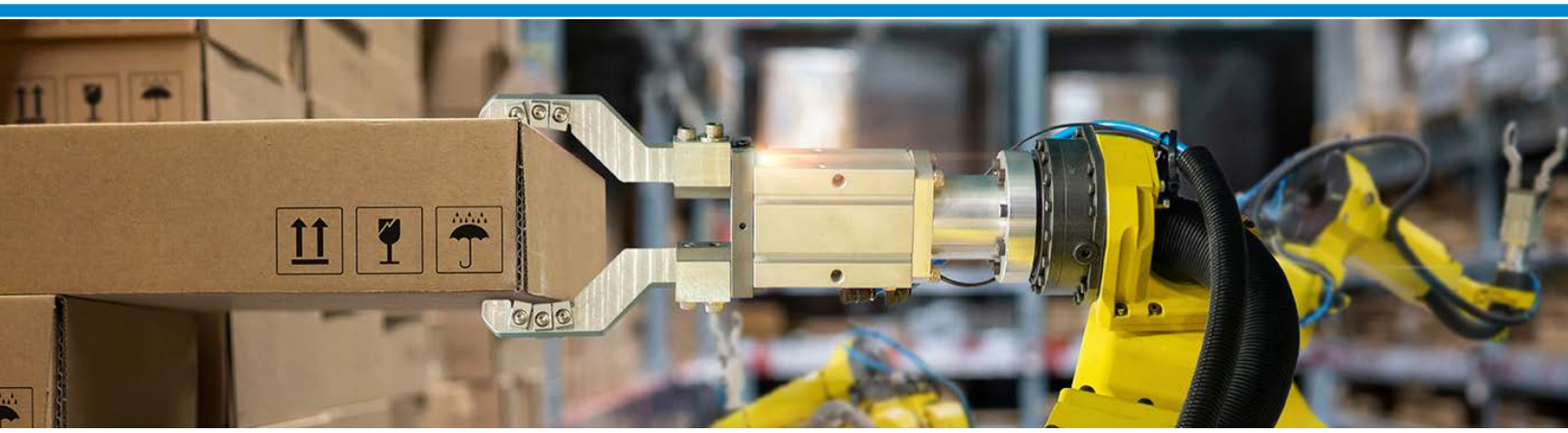
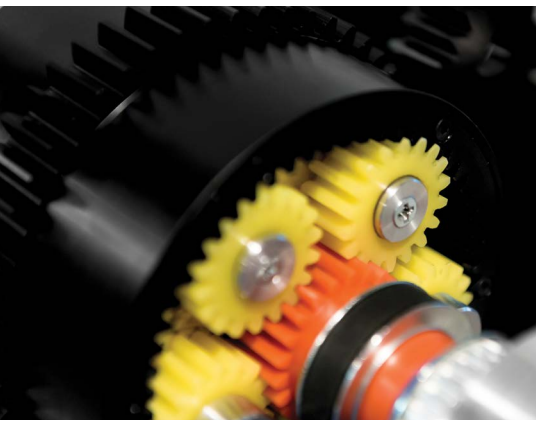
Creep and Stress Relaxation

Welcome to the Delrin® Solution Series, your guide to successful part design with Delrin acetal homopolymer resin. This part of the series provides an overview of creep and stress relaxation, and covers how to more accurately predict the behavior of parts subjected to loads over extended time periods.













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Understanding Creep with Plastic

The aim of this article is to improve your understanding of plastics behavior under long-term loading. If you subject a plastic part to a load over an extended period, you must consider the creep or relaxation that will occur, and how it will result in either increasing deflection or reducing transmitted force.

Why plastics creep

Creep with polymers is a viscoelastic effect due to such materials possessing both viscous and elastic behaviors.

Elastic behavior is the ability of the material to recover its original shape once a force is removed.

Viscous behavior is a measure of a material's resistance to flow. For example, water flows more easily than syrup because it has a lower viscosity. Higher-viscosity materials might include honey, syrups or gels – these will flow at a much lower rate, but any flow becomes a permanent effect. Polymers have an even higher viscosity and therefore show even greater resistance to flow. However, when you apply a prolonged load to a polymer, they too will demonstrate a permanent set behavior, which is often referred to as creep.

Creep happens in polymers because of their structure. They are made up of long molecular chains that are tangled together with weak bonds between them. When a load is applied, these chains can gradually straighten and slip over each other, remaining fixed in place when the load is removed.

Creep and relaxation: what's the difference?

Creep occurs when you subject a part to a constant load, producing an initial deflection followed by a slow increase in strain with time.

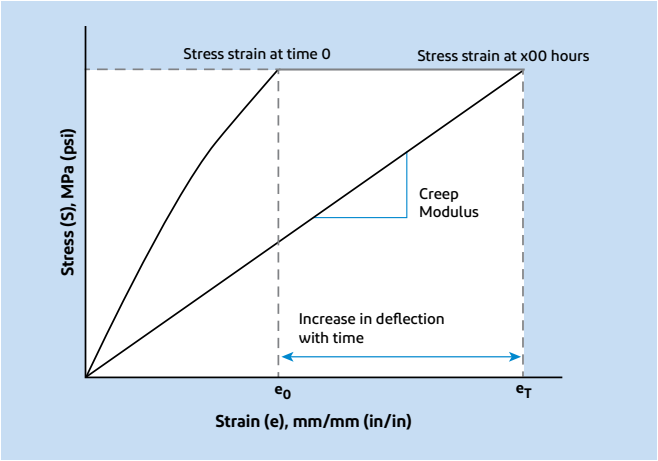


Figure 1. Stress-strain curve showing creep Source: DuPont

If you're designing a part subject to a long-term load, use a creep modulus of the material. This provides an indication of the material behavior at any point in time following loading.

When you remove the load, the deflection is not fully recovered, resulting in a permanent set. This behavior is demonstrated with a spring example in an upcoming section.

Stress relaxation occurs when a part is subjected to a constant strain over time. An example is a spring held in a compressed form. Over time the modulus decreases and, as in the spring example, this reduces the force it can apply.

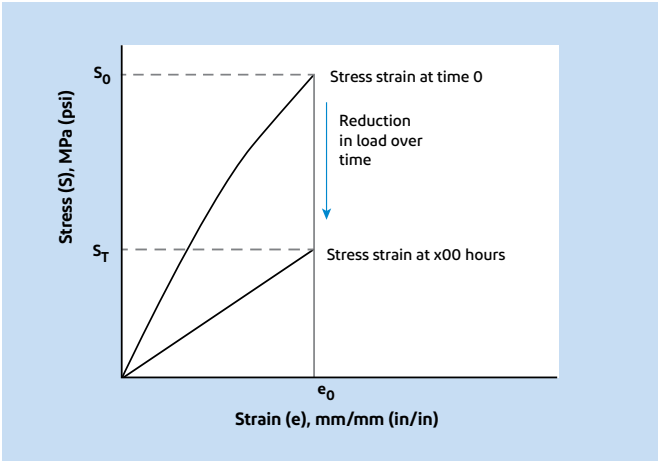


Figure 2. Stress-strain curve showing stress relaxation Source: DuPont

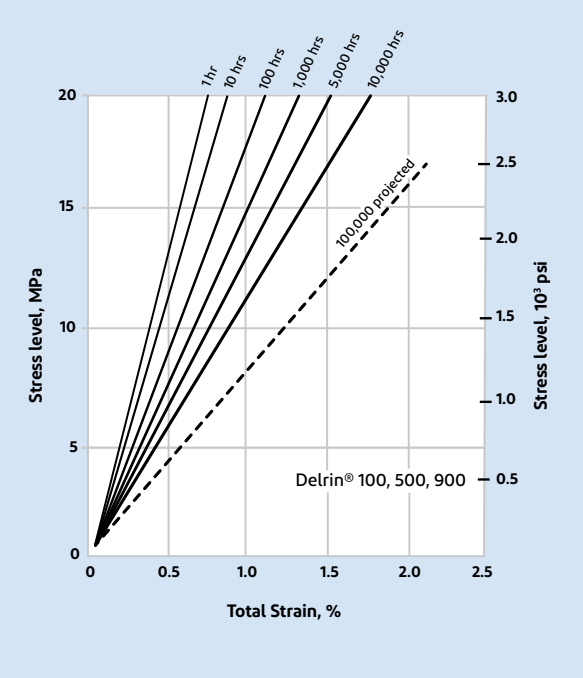
Creep and relaxation: what's the difference? (continued)

Creep and relaxation rates will vary with material composition, temperature, stress level and moisture content. When validating a new part design, it is impossible to assess creep and stress relaxation performance in real time and under all conditions due to the timescales involved. Consequently, designs must incorporate the estimated creep behavior of a particular resin under the load and environmental conditions expected. The more accurate the data, the better the design.

Creep data is often presented in the form of isochronous stress-strain curves versus time at a particular temperature.

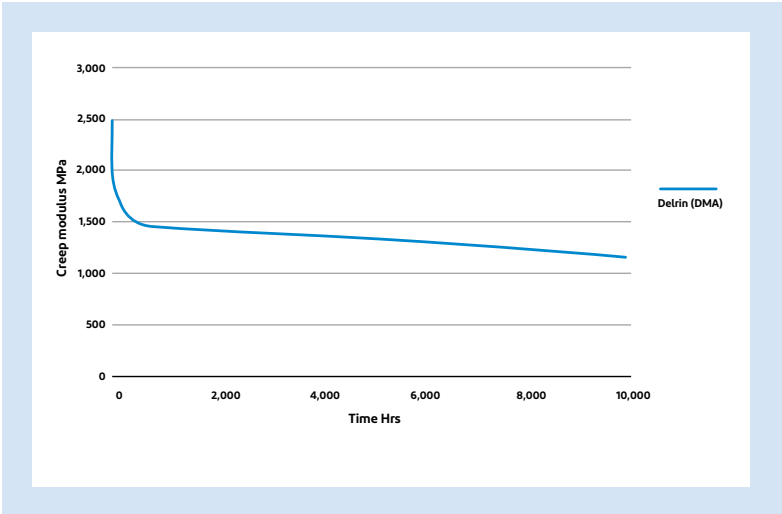
From these charts, you can estimate the increase in strain for a part under constant stress or the reduction in force for constant strain.

It is also possible to convert the data into a modulus versus time graph, which shows that while creep is a long-term effect, it occurs at a faster rate during the first 100 hours.



Source: DuPont

Figure 3. Delrin® isochronous stress-strain curves vs. time



Source: DuPont

Figure 4. Modulus of Delrin® 100 vs. time at 23°C and constant stress of 10 MPa

Looking at a real part

Let's look at what happens when a spring is compressed by a constant load. There is an initial deflection, followed by further compression over time. When the load is removed, there will be a reversal of the initial loading phase and some recovery but not back to its original position. This is called permanent set.

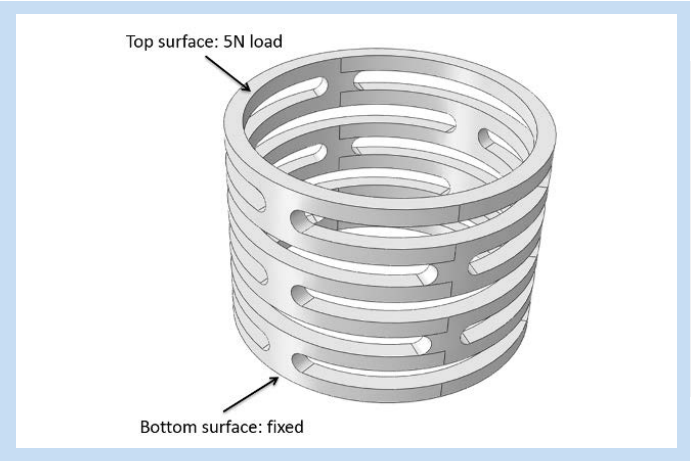


Figure 5. Spring compressed with a constant load of 5N

Source: DuPont

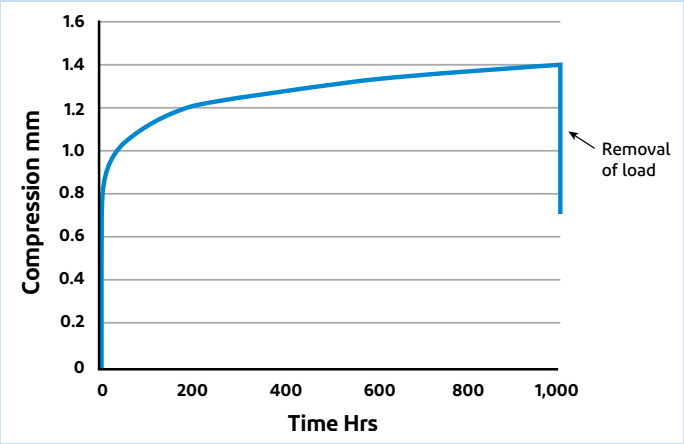


Figure 6. Displacement-time spring demo

Source: DuPont

For a spring compressed with a constant load of 5N, the initial deflection is 0.8mm followed by increasing deflection over 1,000 hours up to 1.4mm.

If the spring is compressed and held in the same position, it applies a reaction force to the object that is compressing it. This reaction force will decrease over time due to relaxation.

Creep with Delrin®

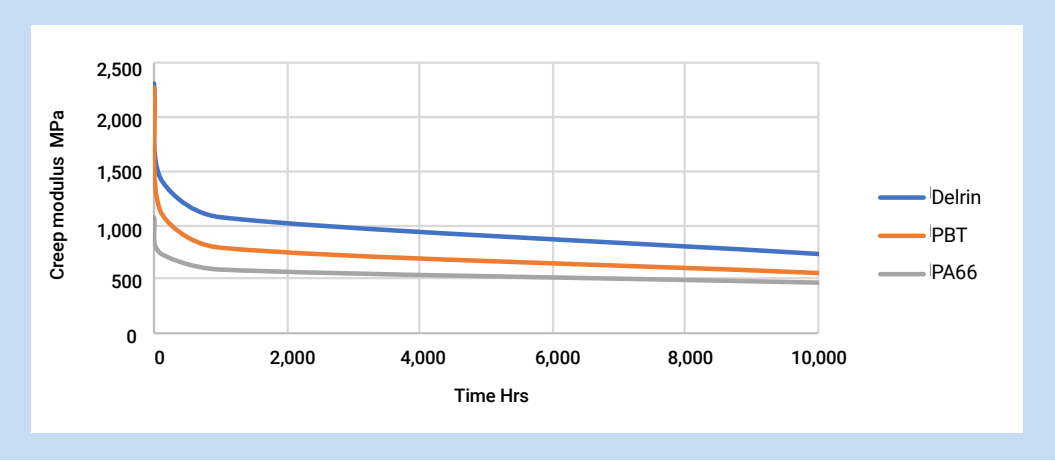


Figure 7. Creep modulus at 10 MPa stress

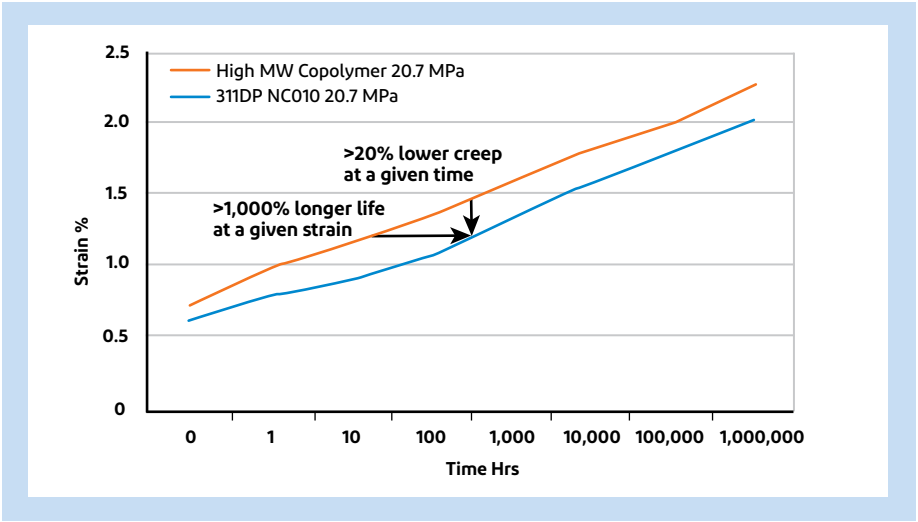
Source: DuPont and Campus Plastics

While unfilled materials might creep at similar rates, the initial stiffness of a material indicates its real usability. When Delrin is compared to PBT and PA66 (Cond), the modulus of Delrin is significantly higher than the other materials throughout the lifetime of the test.

A similar effect can be seen by comparing Delrin® 311DP acetal homopolymer (one of the stiffest acetals) with a similar viscosity copolymer acetal.

Because it is stiffer, Delrin deflects less when first loaded. Although both materials creep at a similar rate, Delrin maintains its initial advantage. In this case, Delrin creeps 20% less under load at any given time.

To think about it another way, Delrin takes over ten times longer to reach a critical deformation point. This is a key performance parameter for a part like a shelf bracket.



Source: DuPont

Figure 8. Comparison of creep performance
Accelerated Flexural Creep at 23°C using DMA. For reference purposes only.



Figure 9. Shelf bracket

Accelerating creep

Creep is an effect of time. So when validating a new product or part design, you will want to accelerate the process by testing at an elevated temperature for a shorter period of time.

Creep testing has been conducted on several Delrin® grades at 25°C, 40°C, and 60°C to measure how much faster creep takes place at elevated temperatures. This helps you estimate the acceleration factor when specifying a test procedure.

In addition to accelerating creep, raising the temperature reduces the modulus of the material. If further testing after creep will take place at room temperature, it is important to understand the recovery when the temperature is lowered.

Studying the unloading of a part

Additional research suggests that a part immediately recovers when a load is removed followed by an additional slower recovery due to the viscoelastic response of the material.
This means there is a less permanent set than traditional creep theory suggests.

Summary

Each individual case of part design is unique due to variables like stress level, time, temperature, unloading, etc. We are here to help. If you are designing a part under long-term load, contact your Delrin representative to access the wealth of data and understanding available.

To learn more, contact your Delrin representative or visit Delrin.com.

Delrin®

Delrin® is an industry-leading premium industrial polymer business. Grounded in strong innovation, Delrin is a category creator with a longstanding reputation for quality, reliability, supply and product performance. The iconic Delrin brand, coupled with proprietary technology and deep application expertise make us a leader in the high-end engineering polymer market. Delrin has exciting growth prospects from exposure to automation, actuation, healthcare, mobility and consumer applications.

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