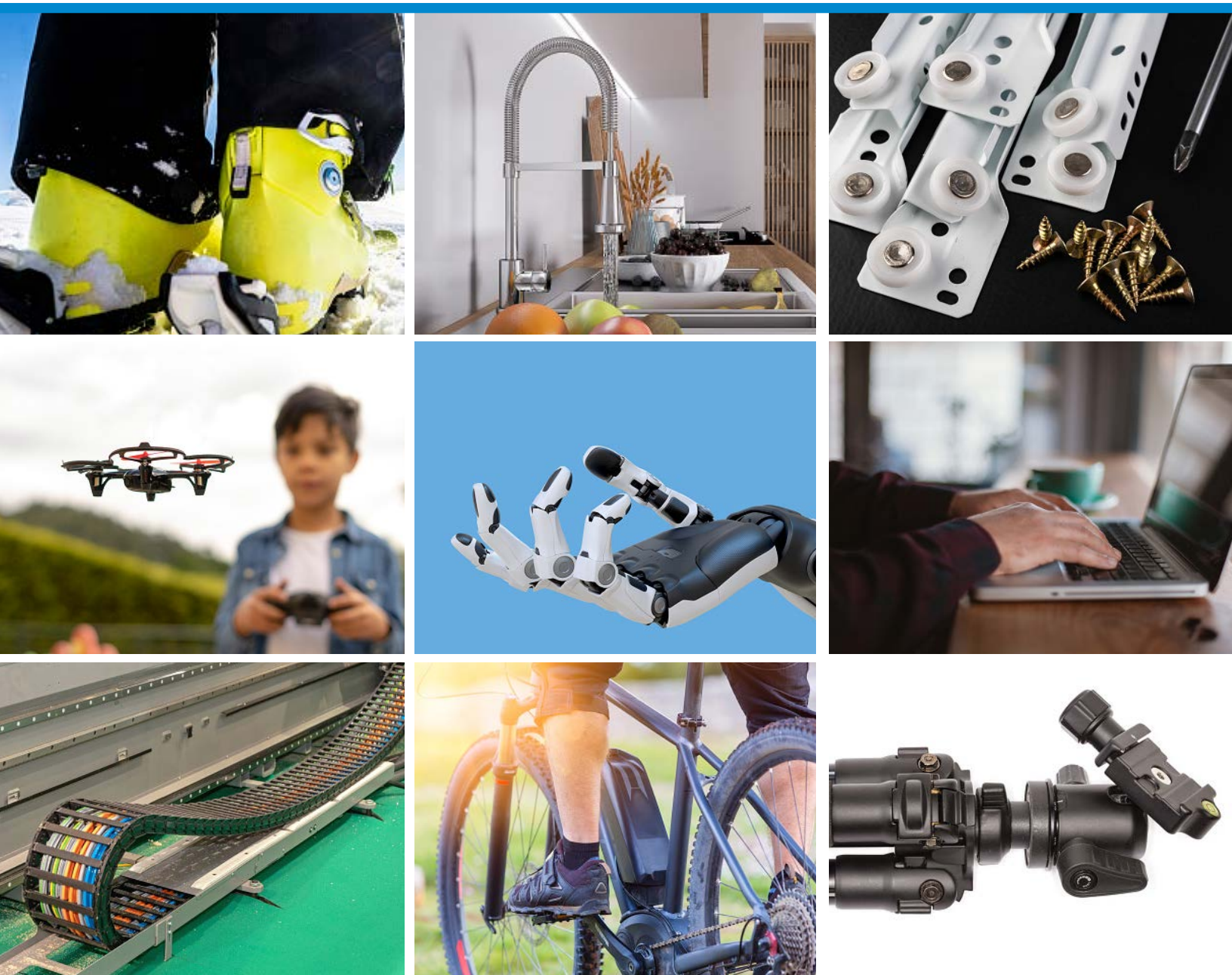
Fatigue Endurance

In this article, we will consider two factors that will affect fatigue performance – choice of material and influence of testing conditions. Since test data is not always available, this article will explain how and why you should interrogate the available fatigue endurance information and discuss applications with technical specialists.



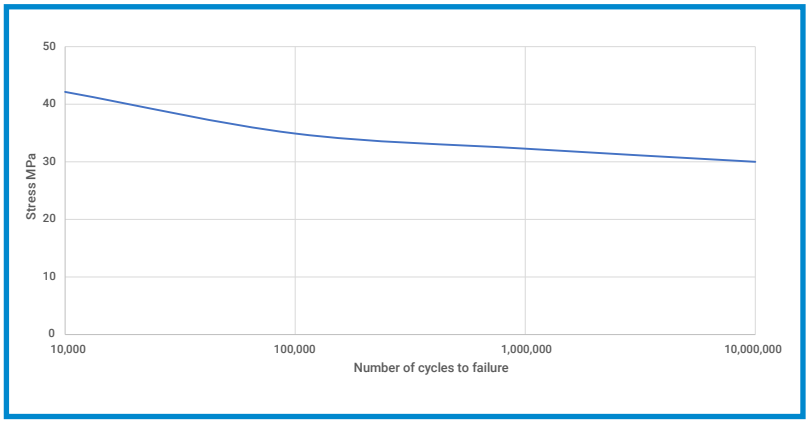
What's Inside

What is fatigue?

Fatigue describes the damage caused by repeated cyclical stresses or deformations whose amplitude does not exceed the ultimate strength of the material.

Delrin® displays high fatigue resistance backed by years of service in safety-critical applications.

When presenting fatigue data, we typically look at the number of cycles to failure at a particular stress in MPa.



Source: Delrin

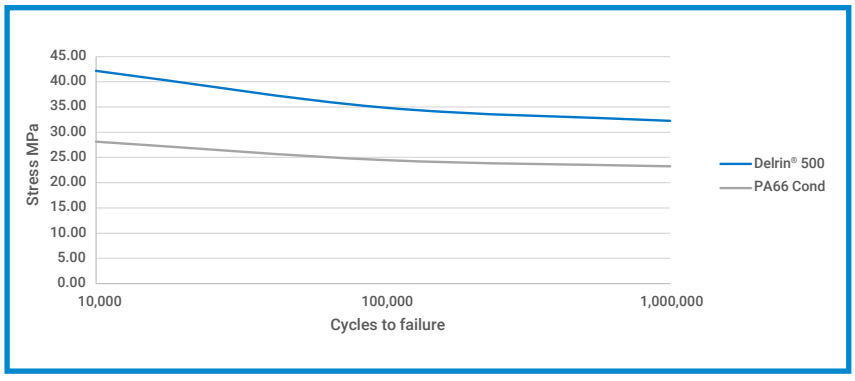
Figure 1. Flexural fatigue of Delrin® 500 (ASTM D671)

Figure 1 shows a logarithmic scale for cycles to failure. If we know the stress level that a part is subjected to, we can use the chart to determine how well the material can withstand a certain number of loading cycles. For example, if the maximum design stress of a part is below 25MPa, fatigue should not be an issue with this grade at 23°C.

This is a simplistic conclusion based on a single load case, and in most cases, the designer will want to understand the performance in more detail.

Choice of material

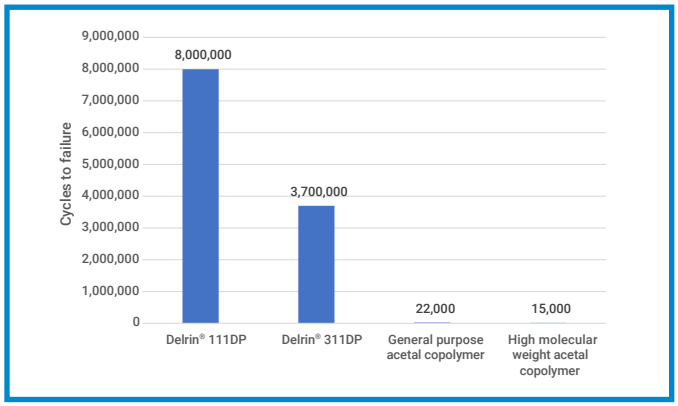
The chart below shows a comparison of an unreinforced PA66 polyamide conditioned at 50% relative humidity (RH) with Delrin® 500 in flexure. We can clearly see the higher maximum design stress that can be achieved with Delrin.



Source: Delrin

Figure 2. Comparison of flexural fatigue of Delrin® at 23°C and unreinforced PA66 (ASTM D671)

Delrin® acetal homopolymer also shows superior fatigue performance versus a similar molecular weight acetal copolymer.



Source: Delrin

Figure 3. Comparison of flexural fatigue of Delrin® and acetal copolymer at 33MPa (ASTM D671)

Figures 2 and 3 were generated by testing in the same laboratory at the same conditions. Unfortunately, there is only a limited amount of public data available to compare the fatigue performance of different materials. This is because the test conditions often differ, which can have a significant effect on the results, making direct comparisons very difficult.

Influence of testing conditions

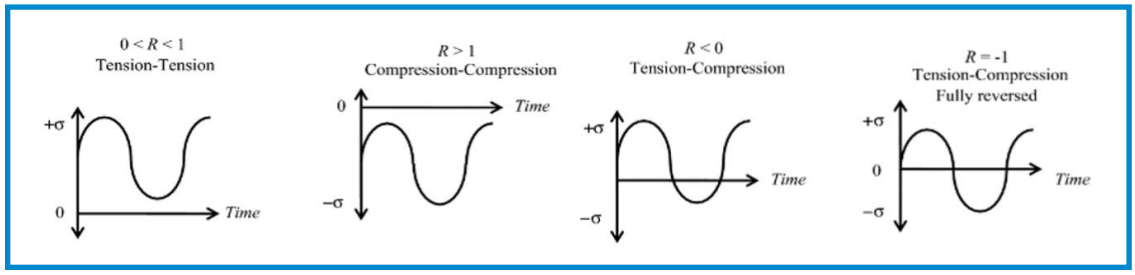
When setting up or analyzing results from a fatigue test, the following factors need to be considered:

1. **Positive stress only or fully reversed load (shown by R number)?**
2. **What is the nominal temperature?**
3. **What is the frequency of the test and what internal heat is generated?**

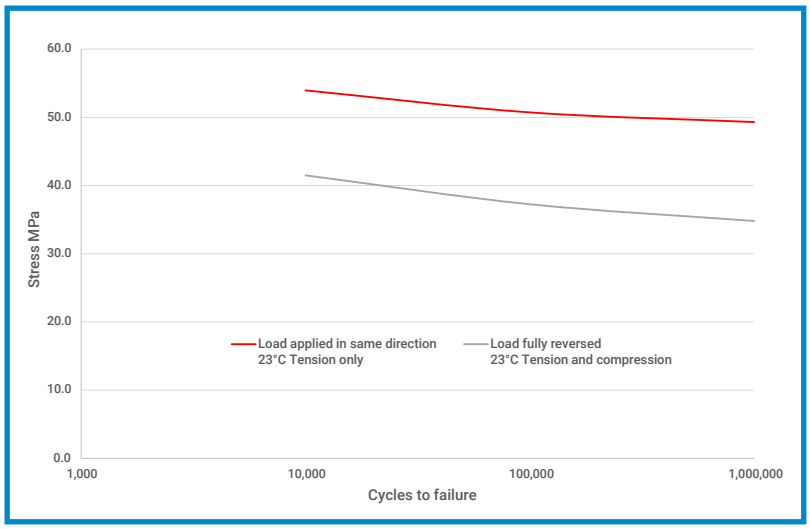
Positive stress only or fully reversed load (shown by R number)?

Sometimes the range of stress put on a part is given by the fatigue stress ratio, R, which is the minimum fatigue stress divided by the maximum fatigue stress: $R = \sigma_{min}/\sigma_{max}$.

This gives an indication of the total difference between the maximum and minimum stress applied to the sample.



As can be seen in the chart below, a combination of tensile and compressive stresses from a fully reversed flexural test (R= -1) is more damaging to the material than a flexural load applied in the same direction each time (R= 0) resulting in a significant reduction in the permissible stress level.



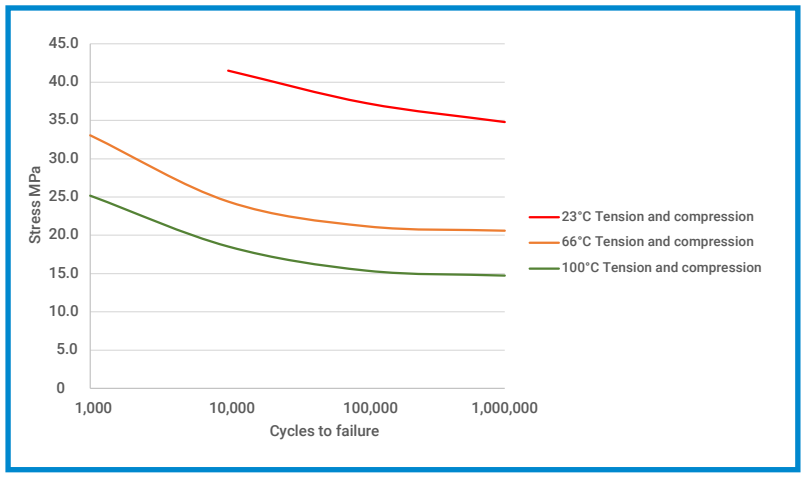
Source: Delrin

Figure 4. Comparison of flexural fatigue in tension only versus tension and compression for Delrin® 500.

An example of where this is relevant is a gear when the maximum allowable stress will be different in a gear that always operates in one direction compared to a gear where the direction is reversed

Test temperature

In some applications, such as automotive gears, fatigue testing is conducted at elevated temperatures to simulate real-life conditions, for example, when a vehicle's electric windows are operated on a hot sunny day.



Source: Delrin

Figure 5. Comparison of fatigue tension and compression at different temperatures for Delrin® 500

As would be expected, the higher the service temperature, the lower the stress level at which the material can survive repeat loading. If elevated temperature fatigue data is not available, a good indication of performance would be to review the change in the stress-strain curves across different temperatures. Be sure to check what extra data the material supplier has in-house.

A good example can be seen below, comparing data for Delrin® with a standard unreinforced polybutylene terephthalate (PBT), which has a significantly lower modulus at 40°C compared to 23°C. This change in properties and subsequent drop in performance would also be seen when running a fatigue comparison at those temperatures.

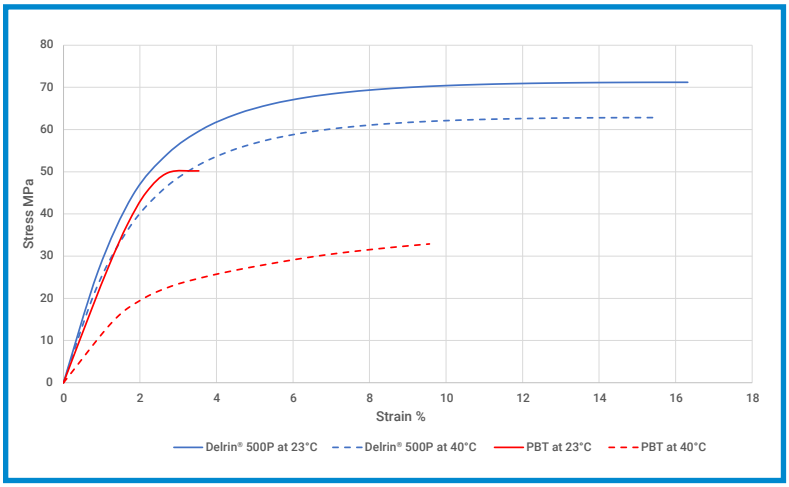


Figure 6. Stress strain properties of Delrin® 500P and PBT at 23°C and 40°C

Source: CAMPUS plastics

Equally important is how the material performs in low temperature conditions. It is more difficult to carry out tests at temperatures below freezing, but the low temperature impact strength gives an indication of the material's robustness.

Delrin® is a proven performer in cold environments with many commercial applications in durable winter sports applications.

Test frequency

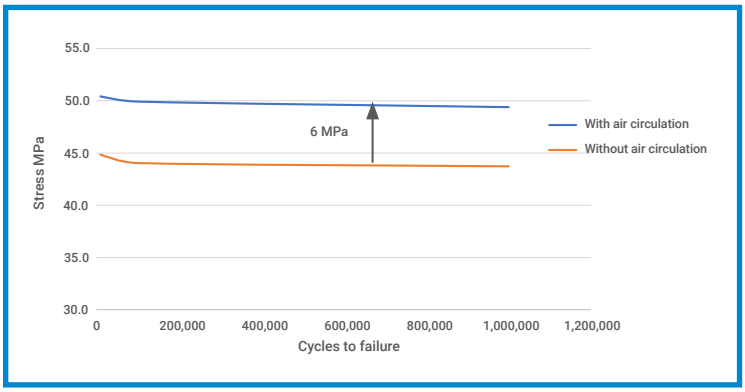
The final point relates to the fact that repeated loading generates internal heating of the part, so the frequency of the fatigue test should be carefully considered when comparing with the frequency of loading of the actual part in service.

Perhaps surprisingly, temperature increases from high frequency testing can be above 15°C, meaning a sample in a room temperature test can easily reach 40°C.

As shown previously, Delrin® is less sensitive to a temperature increase in this range compared with some other unreinforced engineering plastics.

High frequency testing may be appropriate for a gear part with high RPM in service, but less so for a draw roller, which in normal use would not be repeatedly opened and closed at high frequencies. In this case, the test results recorded at high frequencies would prove too conservative, with potential consequences of over-engineering the part in question. This could include designing the part with unnecessarily thick sections or substituting a more expensive material.

The chart below shows that if a fan is used to circulate the air on the sample during the test, it allows the part to cool more effectively. This results in a higher allowable maximum stress.



Source: Delrin

Figure 7. Effect of air circulation on the fatigue performance of Delrin® when tested at 23°C

For complete data visit Delrin® Material Data Center at https://delrin.materialdatacenter.com

In summary. Delrin® is a proven material in fatigue applications, outperforming acetal copolymer, unfilled nylon and PBT, enabling you to design parts that will last longer at higher stress levels or create lighter, thinner wall components.

When delving into specific technical details around fatigue endurance for your application, and which is the most appropriate grade to select, we always recommend that you talk with Delrin technical specialists who can provide the most relevant test information so you can make a meaningful assessment.

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

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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