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How Deflection Range Affects the Performance of Disc Springs

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Disc Springs are conically shaped washers designed to provide predictable and repeatable performance. They may be used to either apply a static load, where the load is nearly constant, or in dynamic situations, where the Disc Spring is experiencing repeated loading and unloading. It is critical to understand how load characteristics affect performance to properly design a system that uses Disc Springs.

Springs are unlike other assembly components; they are designed to deflect and store mechanical energy. The deflection of a Disc Spring is predictable, making it possible to estimate the life cycle of a Disc Spring in an assembly.

Optimal Disc Spring performance is achieved when working deflection is kept between 15% and 75% of full deflection. It is in this range that measured results most accurately match the theoretical characteristics of Disc Springs (*Figure 1*).

The measured characteristic curve in the lower range (less than 15% of full deflection) departs from the theoretical curve due to residual stress. In the midrange of the curve, corresponding to the normal working range of the Disc Spring, the measured and theoretical characteristics are very similar. As deflection increases beyond 75% of full deflection, the force moment arm is reduced and deviation from theoretical characteristics rapidly increases. It is for this reason predictability of force/deflection is restricted to the normal operating range of the Disc Spring.

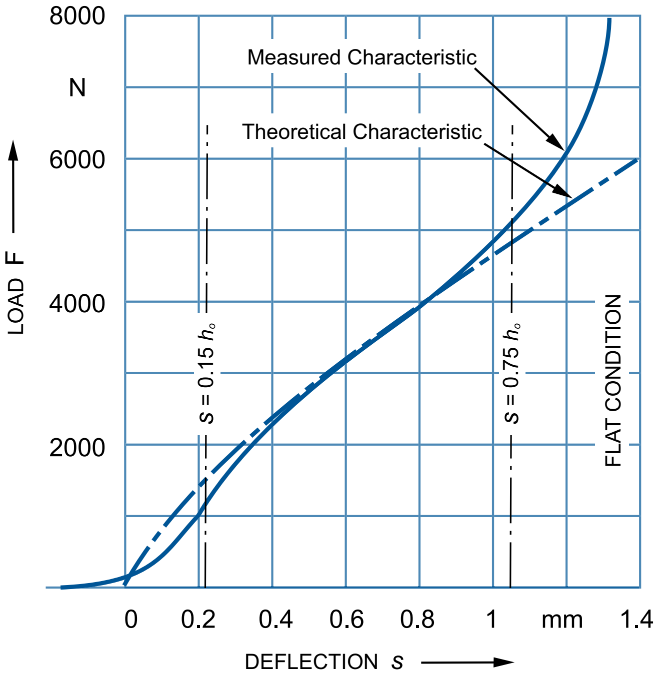

Figure 1: EN 16983, Group 2, Series B 50 x 25.4 x 2 (Formerly DIN 2093)

Disc Life

Static Load

Static loading is defined as carrying a constant load or a load that changes at relatively long time intervals - not exceeding 10,000 cycles for the life of the design. In static applications, the highest calculated stress at mid-span of the top surface of the Disc Spring is critical. (Shown as Point 0 in *Figure 2*.) At this point, the highest calculated stress should not exceed the approximate tensile strength of the material (1400-1600 N/mm²) when the Disc Spring is in the flat position. Standard Disc Springs may be used in static loading without performing theoretical calculation if deflection is kept to less than 75% total.

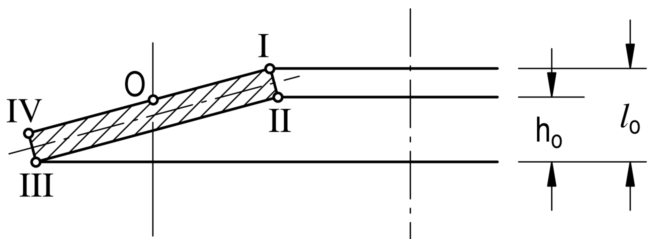

Figure 2

Dynamic Load

Dynamically loaded Disc Springs can be divided into two general categories:

1. Limited fatigue life where Disc Springs achieve 10,000 to 2,000,000 cycles
2. High fatigue life where Disc Springs are able to withstand more than 2,000,000 cycles

Processes such as shot peening may be used to increase the fatigue life of Disc Springs. Shot peening induces favorable compressive stress on the Disc's surface reducing crack propagation.

Residual manufacturing tensile stress occurs at the upper inside diameter edge of the Disc, shown as Point 1 in *Figure 2*:

During operation, this tensile stress changes to a compressive stress. Fatigue life is drastically reduced by this stress reversal. Keeping the Disc Spring under a constant preload at a minimum of 15% deflection eliminates these stress reversals and increases the life of the Disc Spring.

Importance of Pre-Load and Final Load

Pre-Load

Initial loading of the Disc Spring accomplishes two objectives:

1. In unloaded Disc Springs, residual tensile stress from manufacture occurs at Point I shown in *Figure 2*. Pre-loading the Disc changes the tensile stress at Point I to a compressive stress. Keeping the top of the Disc under compressive stress reduces risk of crack propagation. Variation from tensile to compressive stress severely limits the fatigue resistance of the Disc Spring. The Disc Spring must be pre-loaded to a minimum of 15% of total deflection to eliminate tensile stress.

2. The Disc Spring seats as the initial applied force is distributed evenly about the periphery of the spring. Disc Springs are not 100% symmetrical, so there is a slight increase in force as they are seated during pre-load. While this increase in force can be anticipated, it is not accounted for in force/deflection calculations.

Final Load

Increasing final load increases the amount of stress in the Disc Spring and results in lower fatigue resistance. As in any structural component, less deflection results in lower stress and longer life. Loading the Disc Spring past 75% of total deflection takes the Disc past the linear section of the performance curve (*Figure 1*), and stress can increase in a non-linear fashion leading to rapid loss of fatigue resistance. The lower the final load meeting design requirements, the greater the fatigue life.

Fatigue life can be increased by decreasing deflection of the Disc Spring. If additional travel is required, Disc Springs may be stacked to provide more deflection without increasing stress on each individual Disc resulting in increased fatigue life.

Summary

Deflection range of the Disc Spring determines its predictability and endurance.

In static loading, theoretical stress calculations are not necessary provided deflection does not exceed 75% of full Disc deflection. Higher deflections result in high stress that will result in a loss of spring force. Understanding how deflection range impacts Disc Spring life is the key to determining fatigue life.

The guidelines provided in this paper are general in nature; therefore it is recommended that Application Engineers who specialize in designing and specifying Disc Springs be consulted to ensure that the performance requirements are met for each specific assembly.

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