How to Calculate the Estimated Fatigue Life of a Disc Spring

SPIROL WHITE PAPER

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Disc Springs are conically shaped washers designed to provide predictable and repeatable results. This paper focuses on the use of Disc Springs and how to estimate fatigue life in dynamic situations.

In discussing fatigue life, it is important to distinguish between Disc Springs and Conical Spring Washers.

> Disc Springs differ from Conical Spring Washers by design and intended usage. Conical Spring Washers are designed to provide a static thrust load in bolted joints and should not be used in fatigue applications. Conical Spring Washers are specified by DIN 6796.
>
> Disc Springs may be used to apply either static or dynamic loads and are specified by DIN EN 16983 (formerly DIN 2093). Typically Disc Springs have a thinner cross section than Conical Spring Washers. Some variation in size is permissible, but calculations only apply to spring steels and when the ratio of the outside diameter to thickness is between 16 and 40 and the ratio of OD to ID between 1.8 and 2.5.

Deflection of a Disc Spring at a given load is predictable making it possible to calculate force and stress levels in the Disc. As the Disc Spring flexes, stress levels in the Disc change; the greater the change, the faster the Disc Spring fatigues.

Tensile stress at points II and III in *Figure 1* are critical in determining fatigue life. These locations are where fatigue cracks originate. Estimation of fatigue life requires evaluation of the maximum stress difference between preload and final load at locations II and III. The location with the highest stress differential is used to estimate fatigue life. Once it is determined which stress values will be used (from location II or III), the fatigue life charts in DIN EN 16983 can be used to estimate the fatigue life of the Disc Spring.

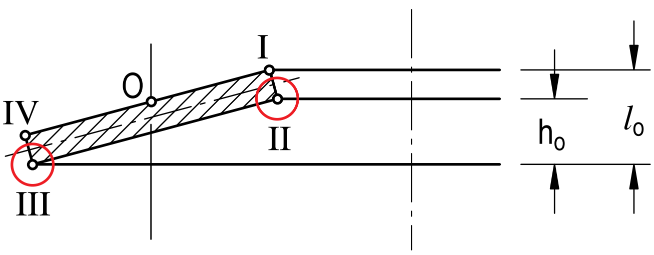

Figure 1: Critical Stress Points within a Disc Spring

Stress values may be found in the Disc Spring product catalog, DIN EN 16983 or calculated using formulas in DIN EN 16984. Fatigue life charts are provided in three thickness ranges: < 1.25mm; between 1.25mm and 6mm and between 6mm and 14mm.

The following examples explain how to interpret the fatigue life charts.

Example 1:

Estimate the fatigue life of a DIN EN 16983 Series B Group 2, DSC 50 x 25.4 x 2 Disc Spring with a preload of 15% of its initial height with a final position at 75% of its initial height.

DIN Series	Dimensions						Design Force, Deflection and Stresses Based on E = 206 kN/mm² and μ = 0.3													
							Preload, $s = 0.15\ h_o$					$s = 0.75\ h_o$					$s = h_o$		
	D_e	D_i	t	l_o	h_o	h_o/t	s	l_t	F	σ_{II}	σ_{III}	s	l_t	F	σ_{II}	σ_{III}	s	F	σ_{0M}
C	50.0	25.4	1.25	2.85	1.60	1.28	0.24	2.61	565	-11	254	1.20	1.65	1,550	312	1,035	1.60	1,646	-1,006
	50.0	25.4	1.50	3.10	1.60	1.07	0.24	2.86	808	32	276	1.20	1.90	2,512	528	1,145	1.60	2,844	-1,207
B	50.0	25.4	2.00	3.40	1.40	0.70	0.21	3.19	1,226	128	264	1.05	2.35	4,762	923	1,140	1.40	5,898	-1,408
	50.0	25.4	2.25	3.75	1.50	0.67	0.23	3.53	1,821	165	312	1.13	2.63	7,217	1,147	1,353	1.50	8,997	-1,697
	50.0	25.4	2.50	3.90	1.40	0.56	0.21	3.69	2,154	204	302	1.05	2.85	9,063	1,301	1,332	1.40	11,519	-1,760
A	50.0	25.4	3.00	4.10	1.10	0.37	0.17	3.94	2,594	249	249	0.83	3.27	11,976	1,418	1,135	1.10	15,640	-1,659

Figure 2: Excerpt from Specification Chart in SPIROL's Disc Spring Catalog

Using the specification chart (shown in *Figure 2*), Stress II (σ_{II}) at 15% is 128 N/mm² and Stress III (σ_{III}) is 264 N/mm². Stress II (σ_{II}) at 75% is 923 N/mm² and Stress III (σ_{III}) is 1,140 N/mm². Now calculate the differences between the stress at each location.

923 N/mm² (Stress II at 75%) – 128 N/mm² (Stress II at 15%) = 795 N/mm²

1,140 N/mm² (Stress III at 75%) – 264 N/mm² (Stress III at 15%) = 876 N/mm²

As seen in the calculation above, the maximum differential in stress occurs at location III, therefore we will use the stress values from location III and the fatigue life charts to estimate the fatigue life of the Disc Spring.

The intersection of a vertical line drawn on the X-axis representing the minimum stress at location III and a horizontal line drawn on the Y-axis representing the maximum stress at location III is the estimated fatigue life. In this example and using *Figure 3*, the line on the X-axis is drawn at 264 N/mm², and the line drawn on the Y-axis is drawn at 1,140 N/mm². The intersection is slightly above the "100,000 cycle" line as represented by N = 10^5 in *Figure 3.* This represents an estimated fatigue life of slightly less than 100,000 cycles.

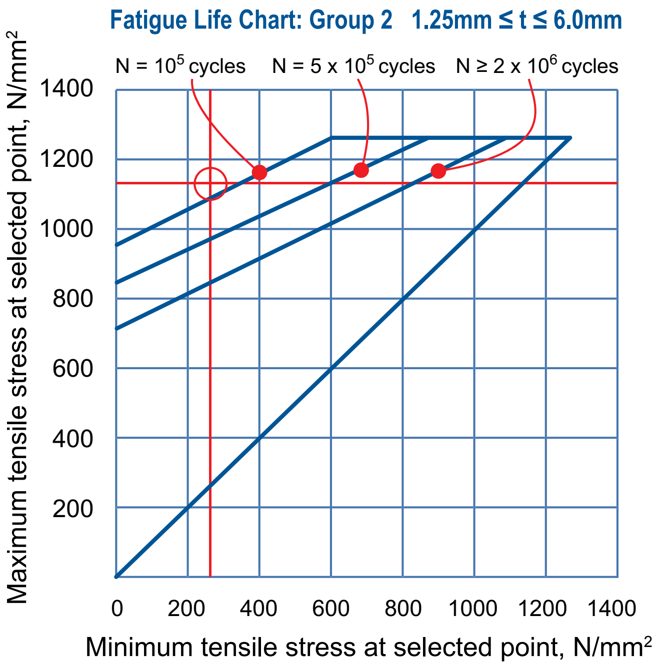

Figure 3: Estimated Fatigue Life for DSC 50 x 25.4 x 2 Disc Spring in Example 1

Example 2:

Estimate the fatigue life of the same DIN EN 16983 Series B Group 2, DSC 50 x 25.4 x 2 Disc Spring with a preload of 25% of its initial height with a final position at 50% of its initial height:

DIN Series	Dimensions						Design Force, Deflection and Stresses Based on E = 206 kN/mm² and μ = 0.3													
							$s = 0.25\ h_o$					$s = 0.5\ h_o$					$s = h_o$		
	D_e	D_i	t	l_o	h_o	h_o/t	s	l_t	F	σ_{II}	σ_{III}	s	l_t	F	σ_{II}	σ_{III}	s	F	σ_{0M}
C	50.0	25.4	1.25	2.85	1.60	1.28	0.40	2.45	854	2	410	0.80	2.05	1,328	106	755	1.60	1,646	-1,006
	50.0	25.4	1.50	3.10	1.60	1.07	0.40	2.70	1,242	74	447	0.80	2.30	2,028	250	828	1.60	2,844	-1,207
B	50.0	25.4	2.00	3.40	1.40	0.70	0.35	3.05	1,949	230	430	0.70	2.70	3,491	537	810	1.40	5,898	-1,408
	50.0	25.4	2.25	3.75	1.50	0.67	0.38	3.38	2,905	292	508	0.75	3.00	5,249	675	959	1.50	8,997	-1,697
	50.0	25.4	2.50	3.90	1.40	0.56	0.35	3.55	3,473	355	494	0.70	3.20	6,437	789	938	1.40	11,519	-1,760
A	50.0	25.4	3.00	4.10	1.10	0.37	0.28	3.83	4,255	424	409	0.55	3.55	8,214	897	787	1.10	15,640	-1,659

Figure 4: Excerpt from Specification Chart in SPIROL's Disc Spring Catalog

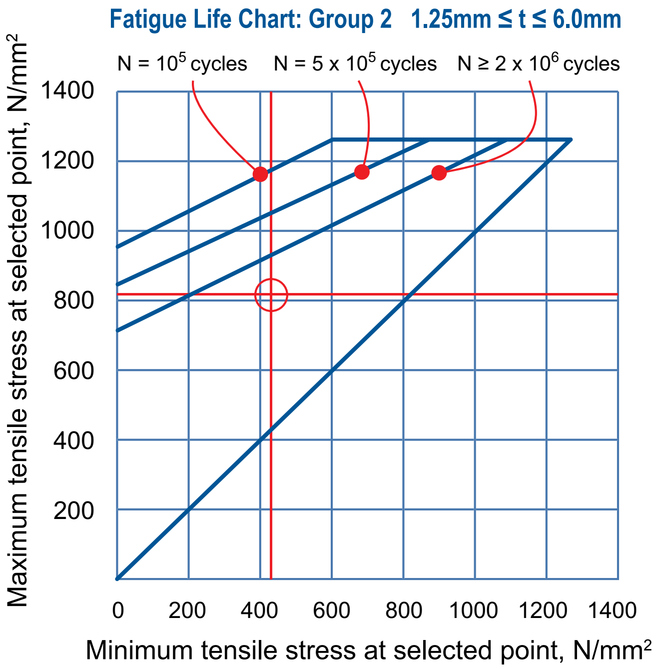

Figure 5: Estimated Fatigue Life for DSC 50 x 25.4 x 2 Disc Spring in Example 2

The maximum differential in stress occurs again at location III. Referencing the fatigue life chart in Figure 5 and plotting 430 N/mm² on the X-axis and 810 N/mm² on the Y-axis, the intersection of the lines is slightly below the 2 million cycle line; therefore the estimated fatigue life is over 2 million cycles.

These examples highlight how a reduction in deflection results in an increase in fatigue life.

Life charts are based on laboratory testing performed on single Discs at room temperature. Testing is done at a frequency that does not result in heat buildup. Test Discs are lubricated and tested on polished anvils; actual fatigue life is likely to be different than values estimated in the fatigue life charts. These charts are valid for single Discs and stacks of a maximum of (10) Disc Springs in series. Discs Springs stacked in parallel will have reduced fatigue life due to heat buildup resulting from friction.

Summary:

Deflection range of the Disc Spring determines its fatigue life. Increasing final load increases stress in the Disc Spring resulting in lower fatigue life. Increasing preload reduces deflection resulting in increased fatigue life. The guidelines provided in this paper are general in nature. Testing is necessary under actual conditions to verify fatigue estimates.

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