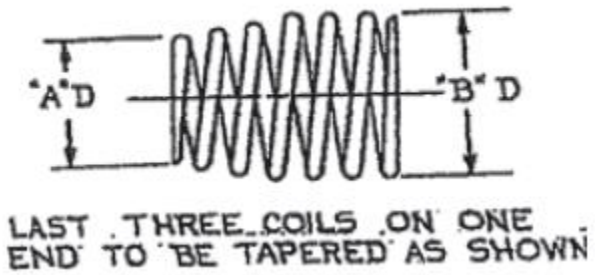
Case Study – Partial Conical Compression Spring

An ASD customer sent in the following design requirement.

Material: Music Wire
Wire Size: 0.045”
Ends: Closed and Ground
Active Coils: 4.3
Free Length: 0.696”
Small Coil OD: 0.375”
Large Coil OD: 0.510”
Load at length of 0.5”: 3 lbf
Load at length of 0.375”: 5 lbf
We also have the following figure…



The first thing to note is that the spring rate changes at the two lengths. At the first length (0.5”), we have a rate of 3/(0.696 – 0.5) = 15.306 lbf/in. Then using the two length/load requirements, we have a rate of (5-3)/(0.5-0.375) = 16 lbf/in. This means that the coil(s) with the largest OD must have deflected to solid before the second load point because the rate will remain constant until that occurs.

We will try using the ASD program for two conical springs in series. We will assume a constant axial pitch. We can specify small ends (barrel shape) but make the one end very close to the large diameter. The program requires some transition coil segments but since they are essentially the same size as the surrounding coils, the exact number won’t matter. We’ll use a quarter coil (0.25) for the transition coils.

If we enter everything as is from the specs (except the loads) and assume 3 tapered active coils on the small end, we get the following load/length results:

Rate Transitions

	Load		Length		Deflection	
At 1st Transition	4.9585	lbf	0.3720	in	0.3240	in
At 2nd Transition	4.9587	lbf	0.3720	in	0.3240	in

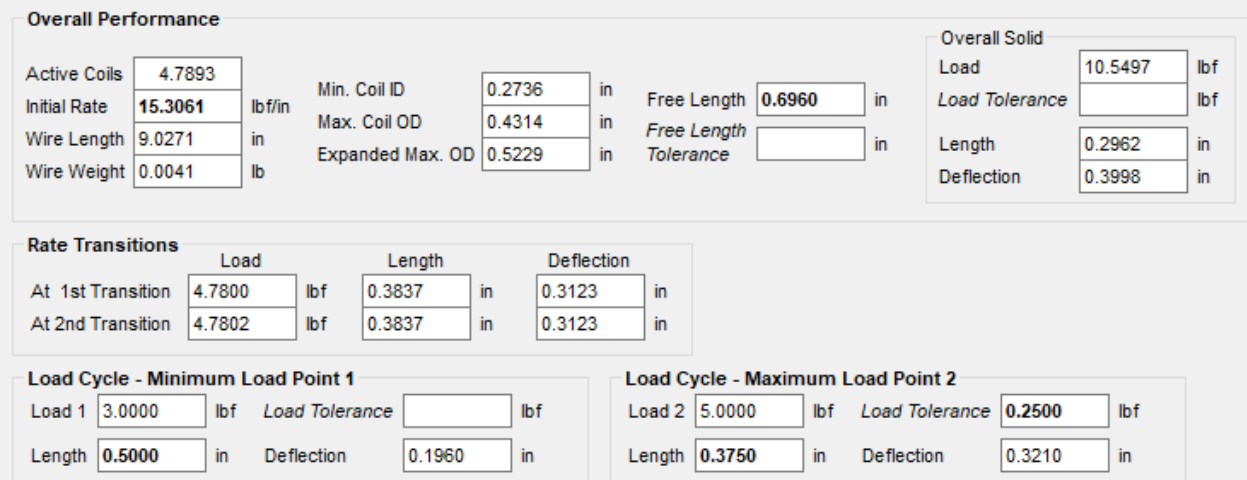
Load Cycle - Minimum Load Point 1

Load 1	3.0000	lbf	*Load Tolerance*		lbf
Length	**0.5000**	in	Deflection	0.1960	in

Load Cycle - Maximum Load Point 2

Load 2	4.9133	lbf	*Load Tolerance*	**0.2500**	lbf
Length	**0.3750**	in	Deflection	0.3210	in

The 2nd length is longer than the first transition point where the largest coils go solid, so the same rate applies and the load 2 value comes up a bit low, 4.9133. That load value is within the required (+/- 5%) tolerance even though it does not match the specs. At this point, we may want to consult with the engineer who produced the specs because the results do not match using the assumption of exactly 3 tapered active coils on the small end. Alternatively, we could try changing the number of tapered coils to see if we can get the results to line up precisely. If we increase the number of tapered end 1 coils from 3 to 3.3278, we get a load of 5 lbf at the 0.375 length.



Overall Performance

Active Coils	4.7893		Min. Coil ID	0.2736	in	Free Length	**0.6960**	in	
Initial Rate	**15.3061**	lbf/in	Max. Coil OD	0.4314	in	*Free Length Tolerance*		in	
Wire Length	9.0271	in	Expanded Max. OD	0.5229	in				
Wire Weight	0.0041	lb							

Overall Solid

Load	10.5497	lbf
Load Tolerance		lbf
Length	0.2962	in
Deflection	0.3998	in

Rate Transitions

	Load		Length		Deflection	
At 1st Transition	4.7800	lbf	0.3837	in	0.3123	in
At 2nd Transition	4.7802	lbf	0.3837	in	0.3123	in

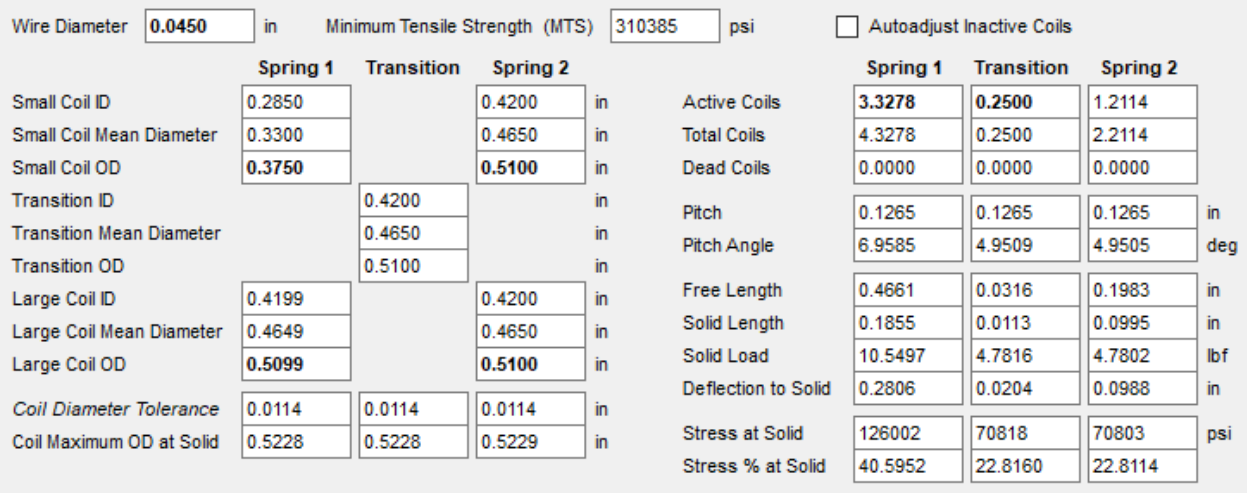
Load Cycle - Minimum Load Point 1

Load 1	3.0000	lbf	*Load Tolerance*		lbf
Length	**0.5000**	in	Deflection	0.1960	in

Load Cycle - Maximum Load Point 2

Load 2	5.0000	lbf	*Load Tolerance*	**0.2500**	lbf
Length	**0.3750**	in	Deflection	0.3210	in

Here are the geometry inputs. Note that for Spring 2, the actual input for the Small Coil OD is 0.50999, just smaller than the Large Coil OD. This is required or the program will report an error indicating that the diameters cannot be the same for a conical spring.



Wire Diameter **0.0450** in Minimum Tensile Strength (MTS) 310385 psi ☐ Autoadjust Inactive Coils

	Spring 1	Transition	Spring 2			Spring 1	Transition	Spring 2	
Small Coil ID	0.2850		0.4200	in	Active Coils	**3.3278**	**0.2500**	1.2114	
Small Coil Mean Diameter	0.3300		0.4650	in	Total Coils	4.3278	0.2500	2.2114	
Small Coil OD	**0.3750**		**0.5100**	in	Dead Coils	0.0000	0.0000	0.0000	
Transition ID		0.4200		in	Pitch	0.1265	0.1265	0.1265	in
Transition Mean Diameter		0.4650		in	Pitch Angle	6.9585	4.9509	4.9505	deg
Transition OD		0.5100		in					
Large Coil ID	0.4199		0.4200	in	Free Length	0.4661	0.0316	0.1983	in
Large Coil Mean Diameter	0.4649		0.4650	in	Solid Length	0.1855	0.0113	0.0995	in
Large Coil OD	**0.5099**		**0.5100**	in	Solid Load	10.5497	4.7816	4.7802	lbf
					Deflection to Solid	0.2806	0.0204	0.0988	in
Coil Diameter Tolerance	0.0114	0.0114	0.0114	in					
Coil Maximum OD at Solid	0.5228	0.5228	0.5229	in	Stress at Solid	126002	70818	70803	psi
					Stress % at Solid	40.5952	22.8160	22.8114	

The ASD Incremental Solver tool was used to repeatedly tweak the Spring 1 Active Coils value while watching the Load 2 value in the Loads tab.

Here's what the spring looks like…